AD NUMBER

AD846612

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution: No Foreign without approval of President, Armed Services Explosives Safety Board, Washington, D. C. 20315.

AUTHORITY

DoD Explosives Safety Board, ltr 7 Jul 2000, 2461 Eisenhower Ave, Alexandria, VA 22331-0600

MINUTES
OF THE TENTH
EXPLOSIVES SAFETY SEMINAR

SHERATON HOTEL

Louisville, Kentucky

13-15 August 1968

Volume I

Sponsor

ARMED SERVICES EXPLOSIVES SAFETY BOARD
Washington, D. C. 20315

Host

U.S. ARMY MATERIEL COMMAND FIELD SAFETY AGENCY
Charlestown, Indiana

651

MINUTES

OF THE TENTH

EXPLOSIVES SAFETY SEMINAR

SHERATON HOTEL

LOUISVILLE, KENTUCKY

13-15 August 1968

Volume I

STATEMENT #2 UNCLASSIFIED

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of ____________________ Sponsor

ARMED SERVICES EXPLOSIVES SAFETY BOARD

Washington, D. C. 20315

Host

U. S. ARMY MATERIEL COMMAND FIELD SAFETY AGENCY

Charlestown, Indiana

PREFACE

Each year a seminar is sponsored by the Armed Services Explosives Safety Board for the purpose of discussing the latest developments, as well as current problems, related to the field of "explosives safety." Attendance represents various agencies of the United States Government and industrial firms performing services to the Government by contract.

The Tenth Annual Explosives Safety Seminar was conducted in Louisville, Kentucky, during the period 13-15 August 1968. Administrative support was provided by the U.S. Army Materiel Command Field Safety Agency, Charlestown, Indiana. Attendance was 475 persons as compared to 417 in 1967, and 300 in 1966. A departure from prior seminars was manifested by the reduction of formal presentations and the expansion of small group discussions, therefor affording an opportunity for the free exchange of information during the three-day period.

Contained herein is much of the material discussed at the 1968 Seminar, although greatly condensed in most cases. Presentations and discussions have no official status, merely representing the opinions and views of the participants.

Volume II contains those portions of the Seminar which are classified CONFIDENTIAL or OFFICIAL USE ONLY and may be ordered from the Defense Documentation Center, Cameron Station, Alexandria, Va. 22314, by qualified users of this service.

B. B. Abrams

B. B. ABRAMS
Colonel, USA
Chairman

TABLE OF CONTENTS

Volume I

Volume II

AUTHOR INDEX

SOURCE INDEX

SIMULTANEITY OF EXPLOSIONS -- WHERE AND WHEN

by

William S. Filler
Naval Ordnance Laboratory, Silver Spring, Md.

This paper is "FOR OFFICIAL USE ONLY" and is

contained in Volume II.

A Manual For Design Of Protective Structures Used In Explosive Processing and Storage Facilities

by

S. Wachtell
R. Rindner

Picatinny Arsenal, Dover, N.J.

INTRODUCTION

For the past 60 years criteria and methods based on results of accidental explosions have been used as a basis for the design of high explosive storage and manufacturing facilities. These criteria, however, did not include a detailed or reliable quantitative basis for assessing a degree of protection afforded by the protective facility and as a result an extensive systematic development program was undertaken to establish procedures which are adequate for current and future design requirements.

The design manual for protective structure, a brief summary of which is presented in this paper, is the product of a ten year systematic engineering and test program prepared under the direction of Picatinny Arsenal by Ammann and Whitney and sponsored by the Armed Services Explosives Safety Board.

The purpose of this manual is to provide a quantitative method of design for protective structures used in high explosive processing and storage facilities - namely to establish methods to prevent detonation propagation between two adjacent buildings, bays and/or cubicles and to establish design procedures and construction techniques for structures used to provide protection for personnel, equipment and/or explosives.

The body of the manual can be divided into 3 main parts as shown in Fig 1, (1) chapters 2 and 3 contain a qualitative description of the 3 components of an explosive systems, (2) chapters 4-8 present quantitative procedures for computing the donor output (both blast and fragments) and structural behavior and (3) chapters 9 and 10 discuss methods of detailing and construction and other features of protective construction such as site planning, closure systems, cost effectiveness and structure motions. Finally, the appendix contains problems and examples to illustrate methods of computing donor output and structural responses.

Qualitative Portion of Manual

Chapter 2

The components of an explosive system, as described in chapter 2 of the manual, and shown in Fig 2 consist of (1) the donor system (explosive material) which produces the damaging output (2) the protective structure, barricade and/or distances which protect against or attenuate the donor output to tolerable levels and (3) the acceptor system (personnel, equipment and/or explosives) which require protection from the donor output.

The donor system includes blast overpressure (which usually is the most important factor in the determining the type and capacity of protective structure), primary fragments resulting from the break-up of the explosive casing and other effects such as fire, electro-magnetic pulse etc. The magnitude of the blast output and fragment velocity are dependent on the chemical and physical properties of the donor system, while the other effects of the detonation are functions of the donor location in relation to the structure.

In this manual protective structures are classified either as (1) shelters or (2) barriers. Protective shelters are used to house personnel and/or valuable equipment while barriers are used for the protection of explosives and other items against the direct effects of blast and fragments. Shelters are defined as structures which provide full protection. Entrances and other oper' gs may have to be sealed off with blast doors, blast valves or blast shie..s. Barriers can be either barricades (reveted or unreveted earth barricades, simple cantilever concrete walls etc) or cubicle type structures where one or mo surfaces of the structure are open to the atmosphere or are of frangible c truction. Earth mounded igloos and other structures are also considered as rriers.

The acceptor system regulates the tolerances and determines the criteria for which the protective system is designed. For a given yield and location of the donor system the type and capacity of the protective structure are selected to produce a balanced design with respect to the sensitivity of the acce r. The acceptor consists of either personnel, equipment and/or other explosive charges.

Chapter 3

Chapter 3 describes qualitatively (1) the methods used for structural design, (2) protection categories (3) acceptor sensitivity and (4) modes of structural behavior.

The method of structural design establishes the response of a protective structure to the blast output resulting from the donor explosion. This

response is expressed in terms of structural design ranges, (a) close-in (b) intermediate and (c) far-out. These design ranges are related to the relative location of the protective structure to the explosion. Although the manual places major emphasis on close-in effects of detonation the other design ranges also are considered in detail.

The established protection levels which govern the safety requirements based on the degree of protection requirements are shown in Fig 3 and are as follows:

a. Protect personnel from fragments, falling portions of the structure and/or equipment and attenuation of blast pressure and structure motion to a level consistent with safety requirements. This protection level requires maximum safety. Protection of personnel is provided with the use of shelter-type structures, where deflections of the wall and roof are limited to a level consistent with the safety requirements.

b. Protect equipment and stores from fragment impact, blast pressures and/or structure motion; and/or protect against release of hazardous materials to uncontrolled environments. This protection level provides the required protection for equipment, weapons and other materials from damaging effects of detonation by blast overpressure and/or fragments. The elements of the structure may be designed for incipient failure condition. Personnel protection in this case will be only incidental. This protection level includes also protection against the release of hazardous materials (such as toxic gases) into uncontrolled environment by requiring the venting of materials into areas where these can be controlled.

c. Prevent communication of detonation by fragments and blast over-pressure. The protection level of the blast walls will depend on the sensitivity of acceptor charges and might tolerate collapse of the walls with controlled fragment velocities, but well below the threshold detonation velocity of the acceptor.

d. Prevent mass detonation of explosives as a result of subsequent detonations produced by communication of detonation between two adjoining areas. This protection level will tolerate propagation of explosion to one adjacent cell, however mass propagation must be prevented. This situation arises in the event of the dissimilarity of construction and/or contents of adjacent cubicles.

Examples of how these protection level categories are utilized in practice are described in chapter 10.

As previously mentioned the acceptor system consists of either personnel, equipment and/or explosive charges. The acceptor sensitivity section describes the tolerance of the above systems to the effects produced by the donor output such as, blast, primary fragments and the motions of the protective structures.

The quantitative data included in this chapter deal with, among others; (a) peak pressure tolerance of the humans (b) boundary (or minimum detonation) velocity of primary fragm nts and (c) maximum permissible acceleration of structure for both equipment and personnel.

The last portion of Chapter 3 which deals with modes of structural behavior, describes qualitatively the results of explosive tests which have been used as a basis for the structural design methods presented in this manual. This description of the structural behavior of a protective structure has been sub-divided into (a) ductile mode (b) brittle mode. The ductile mode describes the behavior of a structural element prior to its failure and is characterized by the elements ability to attain relatively large inelastic deflections. The brittle mode describes the behavior of the element after its failure, the resulting fragments, their size and velocities.

The above mentioned behavior modes have been directed towards reinforced concrete which has been the primary material considered so far in our investigation. Updating of the manual to include other materials of construction, such as structural steel, will be accomplished on completion of tests which are contemplated in the near future.

Chapter 4 - Weapon Effects

The output of the donor (explosive or weapon) system is presented quantitatively in Chapter 4 in tabular and chart forms. This chapter is divided into two parts, (a) blast overpressures and (b) primary fragments. Of the two sections by far the major portion in this chapter is devoted to blast effects of the detonation.

The data presented in this manual pertain to blast output of TNT spherical or hemispherical shaped explosives. However the application of this data to other explosive systems can be made by relating the explosive energy of a given explosive material to its equivalent weight of TNT.

The blast output of the donor system is in the form of air blast pressures as a function of time. The magnitude and distribution of the blast loading arising from these pressures on a protective structure are a function of the following factors: (1) explosive characteristics: (type of explosive material, energy output (high or low order detonation) and weight of the explosive), (2) the location of the detonation relative to the protective structure, (3) the magnification and reinforcement of the pressure wave by its interaction with the ground, barrier or other obstructions and (4) the magnitude and time variation of the initial and subsequent blast waves.

In order to define the above factors the blast loadings on structures have been divided into 2 main groups, based on the confinement of explosive charges, (a) unconfined explosions and (b) confined explosions, (Fig 4). The effects of confinement, height of detonation and its distance from the protective structure determines the blast loadings produced on the structure and are related to the blast load categories illustrated in Fig 4.

The unconfined explosions are subdivided into (a) free air burst loads (b) air burst loads and (c) surface burst loads. These 3 categories will be used primarily in the design of protective structure at some distance from a detonation such as shelters etc.

The confined explosions are subdivided into (a) interior blast loads and (b) exterior blast loads. The interior or close-in blast loads are usually used for structures located close-in to a detonation usually classified as barrier type structures, whereas the exterior blast loads (or leakage pressures) are primarily used for design of structures previously described for unconfined explosions. Although the blast loading categories can be separated and classified individually, no clear-cut limits differentiate each category. In most explosive facilities the various blast environments will overlap, therefore, the design engineer will have to use judgement in application of the above listed recommendations.

The quantitative data presented in this chapter include blast pressure and impulse (both incident and reflected) and other parameters of the blast wave acting either in the free field or on protective structures. As an illustratio of the data, Figure 5 presents the various shock wave parameters for spherical TNT explosive in free air. Here the scaled distance (normal distance divided by cube root of charge weight) has been plotted against peak pressures (both incident and reflected) scaled impulses, and other parameters of both the positive and negative phases of the blast.

The blast effect data presented on this chart were obtained from the literature and adapted for use with other portions of the manual (structural response).

On the other hand other data pertaining to close-in detonations in a partially confined (cubicle type) structure were obtained from tests and subsequent analytical calculations performed in connection with this program. This data were developed for fully or partly vented structures and consist of impulse loads required for design procedures.

A typical impulse chart is shown in Fig 6. The scaled blast impulse (I_b) is related to the various parameters defining a cubicle configuration such as cubicle length, width, height, the normal distance and charge location. Charts like the one shown in Figure 6 were prepared for a great variety of the conditions encountered in actual design situations for cantilever walls and walls with 2, 3, and 4 adjacent reflecting surfaces.

The remainder of the chapter deals with primary fragments and includes the determination of initial and residual velocities of fragments at various distances from the detonation site.

Structure Response

Chapters 5 through 8

Chapters 5, 6, 7 and 8 deal with quantitative procedures for determining structure response to donor output. The first three of these chapters deal with structural rsponse to the blast effects of detonations, while chapter 8 pertains to primary fragment effects.

All four chapters deal with the response of reinforced concrete structures. However upon completion of a projected test program and analysis, these chapters will be supplemented and updated with results obtained on other materials such as shock attenuating materials, structural steel, etc.

Chapter 5

Chapter 5 describes the structural behavior of reinforced concrete elements to blast output in the ductile mode. Included in this chapter is a method for calculating the ultimate strength and therefore the ultimate resistance of concrete elements. These methods include procedures for calculating the ultimate moment and shear capacities of the elements and deflections resulting from the applied blast loads. Recommended static and dynamic properties of both concrete and reinforcing steel and allowable shear capacities for reinforced concrete elements are presented. This chapter includes design procedures for both one-way (cantilever walls or walls fixed on two opposite sides) and two-way elements (walls fixed on 2, 3, or 4 sides as in a cubicle type structure). Presented are tables, charts, and formulas necessary for computing yield lines for various types of element support. Figure 7 illustrates typical idealized yield-line locations for several two-way elements, (walls fixed on four edges, three edges fixed and one edge free and two adjacent edges fixed and two edges free) while a typical curve for estimating yield line location for a two-way element (with adjacent edges fixed and two edges free) is shown in Fig 8.

Similar curves are available for determining the yield-line locations for other two-way elements. Also included in chapter 5 are methods for calculating the strength of two-way elements with openings. The effects of openings on yield-line location is shown schematically in Fig 9.

In general the data and the methods presented in chapter 5 will enable a designer to calculate the various structural properties of reinforced concrete required to perform the dynamic analysis of the element subjected to the applied blast loads.

Chapter 6

Presented in chapter 6 are the methods for performing the previously mentioned dynamic analysis required to achieve a ductile response of a protective structure and its elements under the effects of the applied blast loads.

Preliminary to the presentation of the method of analysis, the relationship between the three components of an explosive system - donor system, acceptor system and protective structure - are defined as shown in Fig 10. The consideration of the properties of the first two components (donor and acceptor) define the parameters necessary for the structural design of the last component (protective structure). The relationship between these parameters, which are described with the use of a typical resistance-deflection diagram (Fig 11) will define the methods of analysis required to define the ductile or brittle behavior of the individual structural elements and the protective structure as a whole. The parameters shown in this diagram include the structure's resistance in both elastic and plastic range, maximum rotation in the ductile mode, response or deflection criteria, protection categories, types of protective structures, design ranges, structure load sensitivity, design methods, design stress, shear reinforcement and brittle mode of wall failure (spalling, crushing, scabbing).

The principles of the dynamic analysis, presented in chapter 6, are for protective structures located at close-in, intermediate, and far-out ranges. These analysis include analytical procedures utilizing a single degree of freedom dynamic system for their solution as shown in Fig 12. In addition to methods of analysis, tables, charts and formulas are presented which define impulse capacities of the structural elements located close-in to detonation as a function of various structural parameters such as the maximum allowable deflection, effective mass and strength. Working tables and charts are presented for both one- and two-way concrete elements. Included are charts which permit the designer to obtain the optimum ratio of vertical to horizontal reinforcement in order to estimate the maximum impulse capacity for several types of two-way structural members.

A typical chart mentioned above is shown in Fig 13 where the ratio of vertical to horizontal reinforcement (p_V/p_H) is plotted against the impulse coefficient (c) for various length to height ratios of the element. Similar design charts were prepared for elements with 2, 3, and 4 adjacent edges fixed, simulating the side wall, back wall and a back wall with a blast roof in a cubicle type structure. Further charts are also presented to estimate the shear coefficients required to calculate lacing and other shear reinforcement for various above mentioned slab configurations. A typical graph relating the shear coefficient (C_V) with x/L ratio is shown in Fig 14. (It should be noted that crack lines as represented by, x, can be obtained for a given condition from Fig 5-10 in the manual.)

Finally procedures are presented to determine the ductile mode of response of composite walls. These procedures take into account that portion of the blast impulse which is resisted by the energy absorption capabilities of the sand section of the wall.

Chapter 7

The response of a structural element in the brittle mode, discussed in Chapter 7, consists of that structural behavior which is associated with either partial or total failure of the element and is characterized by two types of concrete fragmentation, (1) spalling, which is the dynamic disengagement of the surface of the elements and (2) post-failure fragmentation which is associated with structural collapse.

Spalling is only critical when personnel, valuable equipment and highly sensitive acceptors are involved (category 1). In this case spalling must be either prevented or contained. On the other hand for prevention of propagation to explosives such as TNT, Comp B etc, spalling can be tolerated. In the latter case the post-failure secondary fragment become critical.

Direct spalling of a concrete element as shown in Fig 15 is the result of tension failure in the concrete normal to its free surface and is caused by the shock pressure of an impinging blast wave transmitted through the element.

Another form of spalling may occur which is referred to as scabbing and is the end result of a tension failure in the concrete. Scabbing is usually associated with large deflections, causing crushing of the concrete perpendicular to the free surface (Fig 16).

Various procedures for minimizing the effects of both direct spalling and scabbing are presented in Chapter 7, and include separation distances and mechanical means. The specific system used to protect against spalling will be dependent on the configuration and response of the protective structure.

Failure of an unlaced element (Fig 17) is characterized by the dispersal of relatively small high velocity concrete fragments. Laced concrete elements exhibit a failure characterized by reinforcement failures occurring at points of maximum flexural stress, with the section of the element between the points of failure remaining essentially intact. Quite often if the overload is not too severe, the compression reinforcement at the hinge points do not fail and thereby prevents total disengement of the sections between the hinges (Fig 18). In other situations, where there is an excessive overloading of the element, the failed sections of the laced elements are completely disengaged and displaced from the structure. However their velocities are usually less than the maximum velocity of the element at incipient failure.

The calculation of fragment mass and sizes as a function of various blast parameters for both laced and unlaced elements is discussed in this chapter. Presented are charts relating fragment coefficient with the ratio of vertical to horizontal reinforcement for panels fixed on two, three and four edges. Equations are presented for calculation of the kinetic energy of the fragments after wall failure as a function of applied blast impulse, fragment coefficients and other known wall parameters.

Chapter 8

Chapter 8 deals with structural behavior to primary fragment impact resulting from the breakup of explosive casing. These fragments travel with initial velocities in the order of several thousand ft/sec. Upon contact with a barrier the fragments will either pass through, be embedden in, or deflected by the structural element properties of both the armour-piercing fragment and the concrete. Figure 19 is a plot of the maximum penetration of the armour piercing fragments through 5000 psi concrete for various fragment sizes and striking velocities.

To estimate the concrete penetration of metal fragments other than armor-piercing a procedure has been developed where the concrete penetrating capabilities of armor-piercing fragments have been related to those of other metals. This relationship can be expressed by a constant and the numerical values for several of the more common metals are listed in Fig 20.

The secondary fragment velocities associated with spalling resulting from fragment impact are usually very small (less than 5 ft/sec) except when blast pressures are involved. In this case the secondary spall fragments may be accelerated resulting in higher velocities.

To evaluate the effects of primary fragments on composite (concrete-sand-concrete) barriers, the penetration of the fragment through both the concrete and the sand must be considered. In most cases the chance of penetration through a composite wall by primary fragments is negligible.

Chapters 9 & 10

Construction Details and Procedures

Chapter 9 deals with the construction details and procedures. This chapter describes the differences in detailing and construction of structures designed to resist the blast output with particular attention directed toward the construction of concrete structures located close to a detonation.

Construction methods for both laced andunlaced reinforced concrete are presented. Laced elements are usually used in those facilities which are designed to resist the explosive output of close-in detonation (high intensity pressures with short duration). The functional requirements of these facilities normally specify the use of a series of interconnecting structural elements (walls, floor, slab and roof) forming several compartments or cubicles. Because of this cubicle arrangement, the walls separating the individual areas are the critical component in the design.

Although the construction of laced reinforced concrete structures is similar to conventional structures, some changes in the fabrication and construction procedures are required to insure full development of both the strength of the concrete and the reinforcement well into the range of plastic action of the various elements.

Included in this chapter are typical lacing schemes (Fig 21), typical details for splicing of flexural bars (Fig 22), and lacing. Several other charts show the mechanics of or placement of flexural and lacing reinforcement in the protective structure. This chapter will illustrate to the design engineer how to achieve proper detailing of reinforcement and sequence of construction required to achieve the full intent of the design.

Chapter 10

Discussed qualitatively in Chapter 10 areother items, in addition to the structural requirements to resist blast pressures and primary fragments, required in the design of protective structures to resist high explosive detonations as shown in Fig 23: (1) site planning to achieve a safe and operationally efficient facility, (2) cost effectiveness to achieve economical design of both protective structure and of the overall layout of the facility, (3) proper location and arrangement of entranceways and methods of closures for openings in shelters and (4) protection against structure motions.

Proper siting will usually be specific to each facility. However, certain guide lines can be established which will reduce construction costs, optimize safety and facilitate operation requirements. The chapter discusses a practical case of the application of 4 protection levels (discussed previously in chapter 3) into actual design, such as planning of individual structures, site planning etc. Illustrations are presented to illustrate the guide lines for site planning. Fig 24 shows the site planning of a typical Ammunition Maintenance Facility. This facility consists of 6 main components interconnected with roads, walkways and railway. Minimum explosive separation distances indicated are in accordance with the minimum requirements of the AMC Safety Manual. The separation between the steel-arch magazines and missile and rocket stand provides a level of protection consistent with protection category 3, where prevention of communication of detonation by fragment and high blast pressure is required. The separation between the vacuum collecting building (200 lbs. of HE) and the Maintenance Building (5,000 lbs of HE) is based on 200 lbs in the Vacuum Building since using 5,000 lbs of HE as the basis for separation would be highly uneconomical and unwarranted. This latter design technique conforms to Protection Category 4 where prevention of mass detonation is mandatory but propagation into one adjacent cell with a much smaller quantity of HE is permitted.

The cost effectiveness section of Chapter 10 discusses the cost reduction achieved by proper design of the individual elements, and in particular proper design of laced concrete elements.

To illustrate the cost effectiveness study as applied to actual design, consider a cantilever wall 15 ft high and 45 long with a 1 ft by 1 ft haunch located at the base slab. The walls were designed to resist the blast output from a maximum weight of 7,500 lbs. of HE located at 12.5 feet from their surface.

Results of cost analysis, considering the use of laced reinforcement and based on incipient failure criteria, are shown in Fig 25. As can be seen from the chart, the cost of the wall designed to resist 1,000 lbs explosion would be $79/cu yard which is the magnitude of conventional concrete structure cost. The analysis also indicates that, to obtain minimum construction cost, the thickness of the wall should be increased as the charge weight increases. This concrete thickness should be compatible with flexural reinforcement.

For comparison purposes, the costs of laced single walls (designed to approach incipient failure) are compared with costs of composite walls designed for the same protection,and also compared with costs of laced walls with controlled fragment velocities of 100 ft/sec. For the range of charge weights considered, composite construction is more expensive. Furthermore larger wall sections are required. However, at very large charge weights both cost and concrete thicknesses of composite walls approach those of laced single walls.

As may be expected, the post-failure fragment criteria result in substantial cost reduction. For charge weights of greater than 1,000 lbs the cost for walls, designed forpost-failure fragment criteria, is approximately one-half the walls designed for incipient failure. It should also be stressed that although the cost of the 12" standard Reinforced Concrete wall is approximately the same as that of minimum laced walls (10" thick) the charge capacity of the standard walls is one-third that of laced walls designed for residual fragments velocities of 100 ft/sec.

The blast closure system section describe methods for sealing off openings to prevent the blast pressure leakage, entrance of fragments, dust, heat, toxic gases etc into areas which must be protected against the effects of an explosion. Blast closure systems comprise devices or structural elements which protect access or ventilation openings of a shelter such as blast doors, blast valves or shields.

Blast doors may be used to provide shielding against blast, fragments, and provide opening for personnel and vehicles, fire heat, etc. Fig 26 illustrates typical solid build-up steel plate door. This type doors may be used to seal openings in those elements designed for the blast effects associated with the close-in design range. The steel plate is capable of resisting and transferring the high local shear stresses produced by non-uniform blast loads.

Blast valves provide closures for ventilation openings. Unlike nuclear explosion, most conventional type explosive systems will not generally require blast valves. However blast pressure leakage into a structure must be investigated relative to the structure's content (personnel, equipment) to verify the fact that the blast valves need not be used.

Motions of structures considered in this manual may be classified as (1) Those motions which are induced by themotion of the ground below the structure as a result of ground shock and (2) motions caused by the transient effects of the air-induced shock wave traveling across the structure. Except for very large explosions the motions produced by the ground shock will usually be small in comparison to the motions produced by the blast loads and therefore may be neglected.

This chapter describes some of the systems used to minimize the effects of structure motion. This includes a shock isolation system (consisting of spring and platform arrangement) and other protective materials (clothing and restraining devices). Protection capabilities of the system are related to protection tolerances for structure motion mentioned previously in chapter 3.

Finally the appendix consists of illustrative examples on weapon effects and structural behavior and structural design for great many situations encountered in actual design problems.

CHAPTER 1	gives background and guide lines
CHAPTERS 2 & 3	contain qualitative description of the 3 components of the explosive system
CHAPTERS 4 through 8	present quantitative procedures for computing donor output and structural behavior
CHAPTERS 9 & 10	discuss methods of detailing construction as well as site planning, cost effectiveness, protective closures and movement of structures.
APPENDICES A through E	give illustrative problems in weapon effects, structural behavior and design

Figure 1

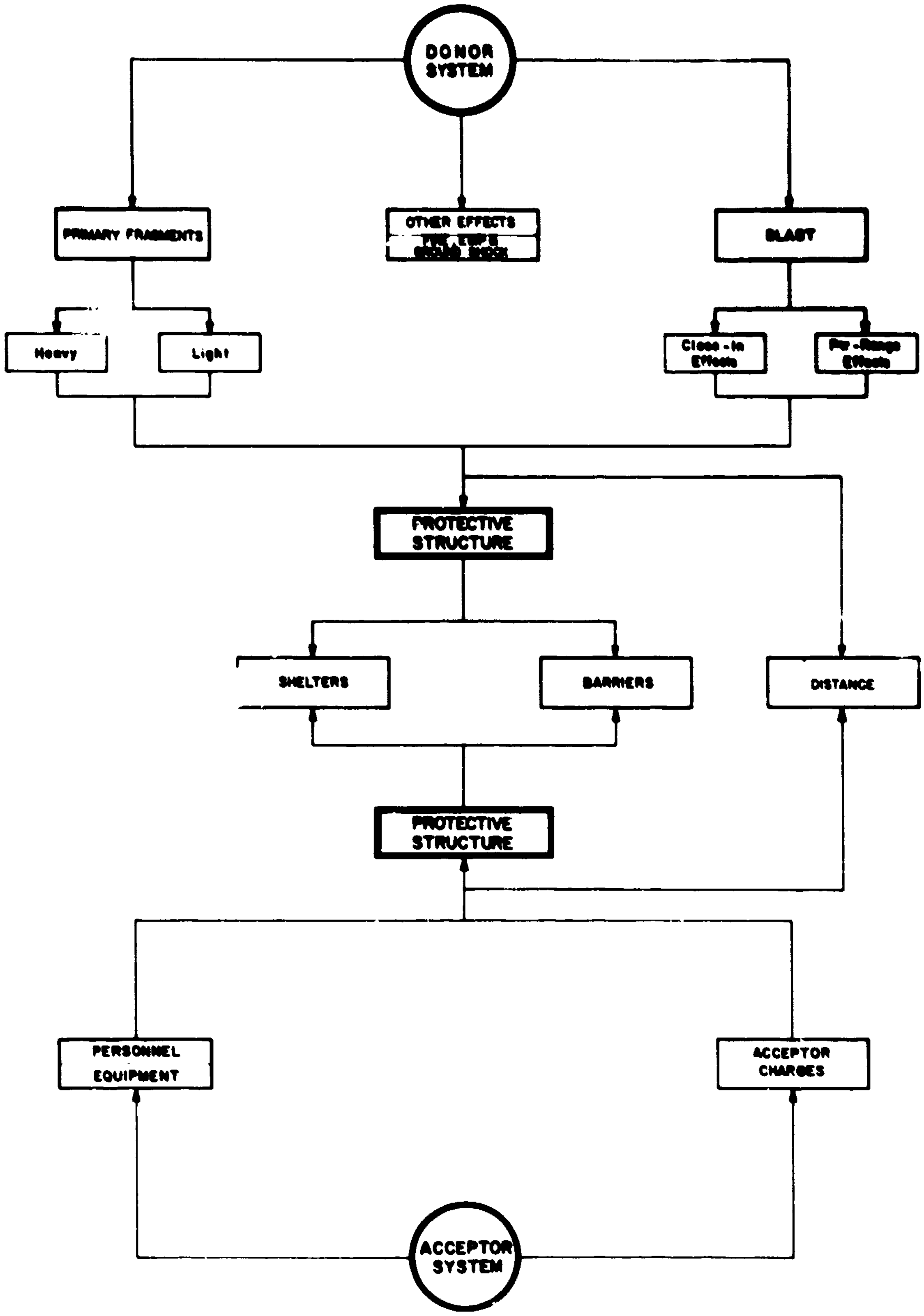


Figure 2 EXPLOSION PROTECTIVE SYSTEM

PROTECTION CATEGORIES

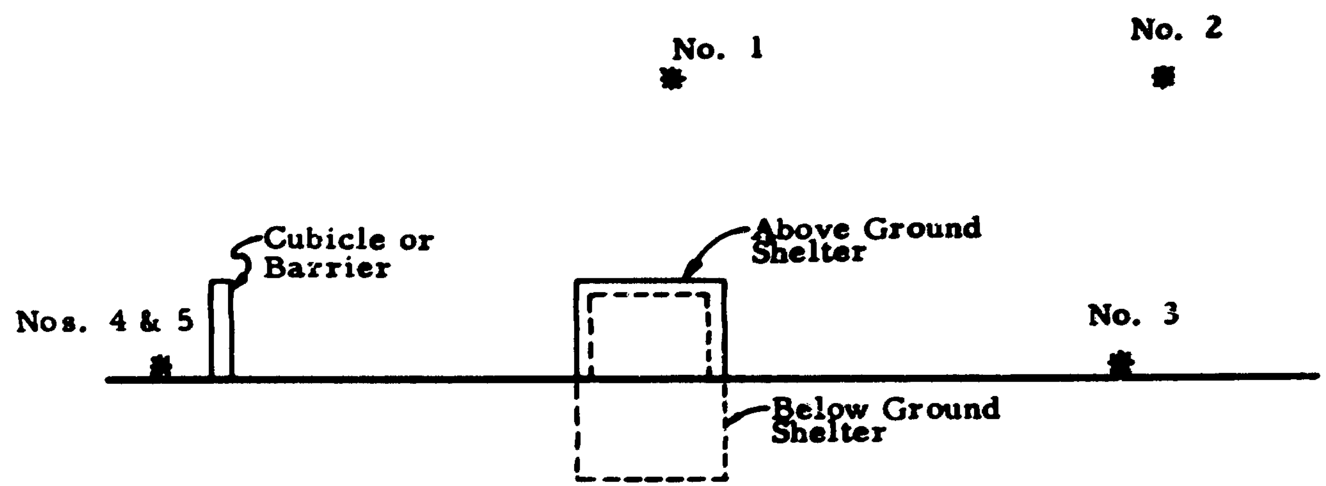
1) Protect personnel from fragments, falling portions of the structure and/or equipment and attenuation of blast pressures and structural motion to a level consistent with safety requirements.

2) Protect equipment and stores from fragment impact, blast pressures and/or structural motion; and/or protect against release of hazardous materials to uncontrolled environments.

3) Prevent communication of detonation by fragments and high blast pressures.

4) Prevent mass detonation of explosives as a result of subsequent detonations produced by communication of detonation between two adjoining areas.

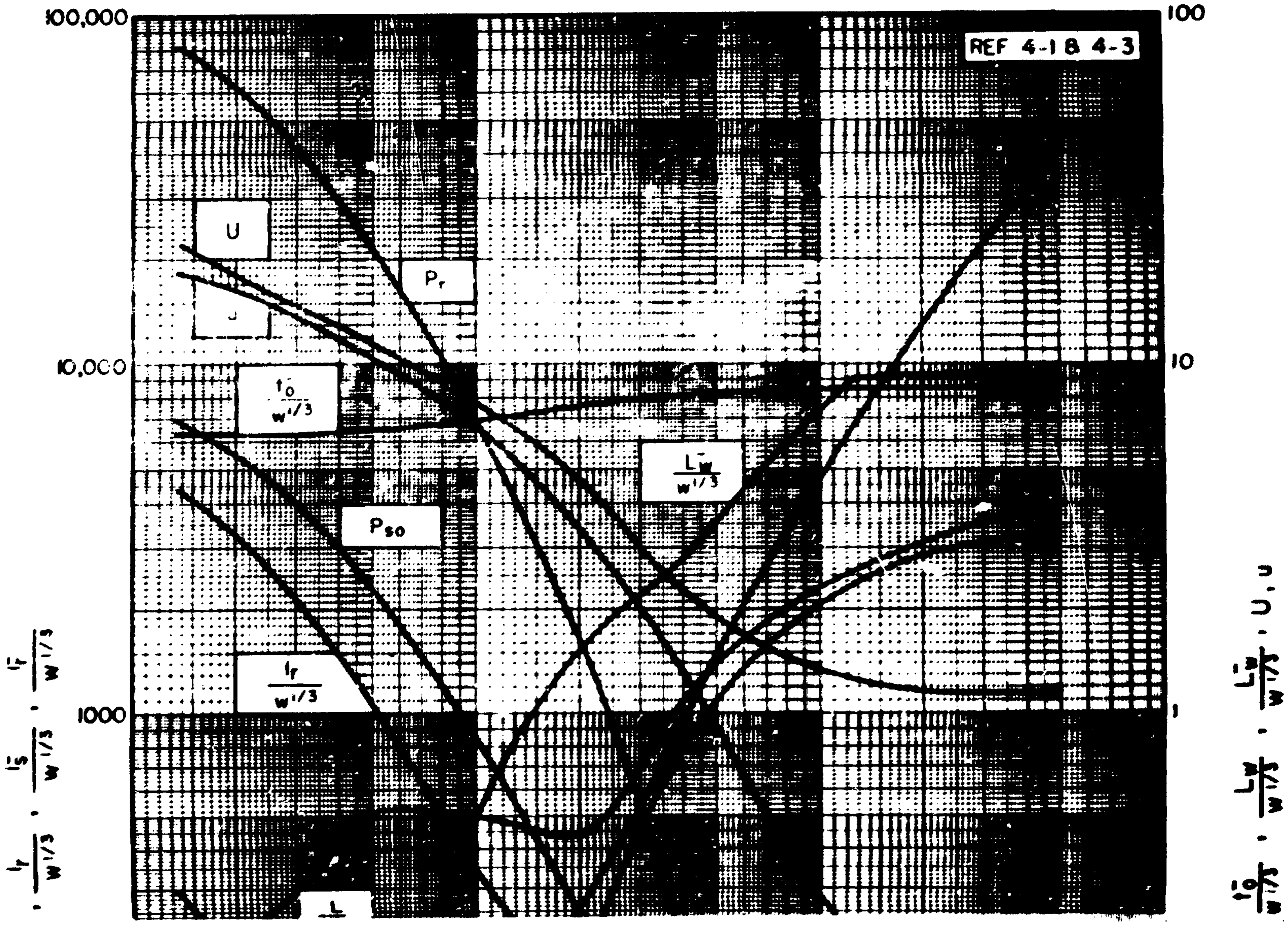
Figure 3

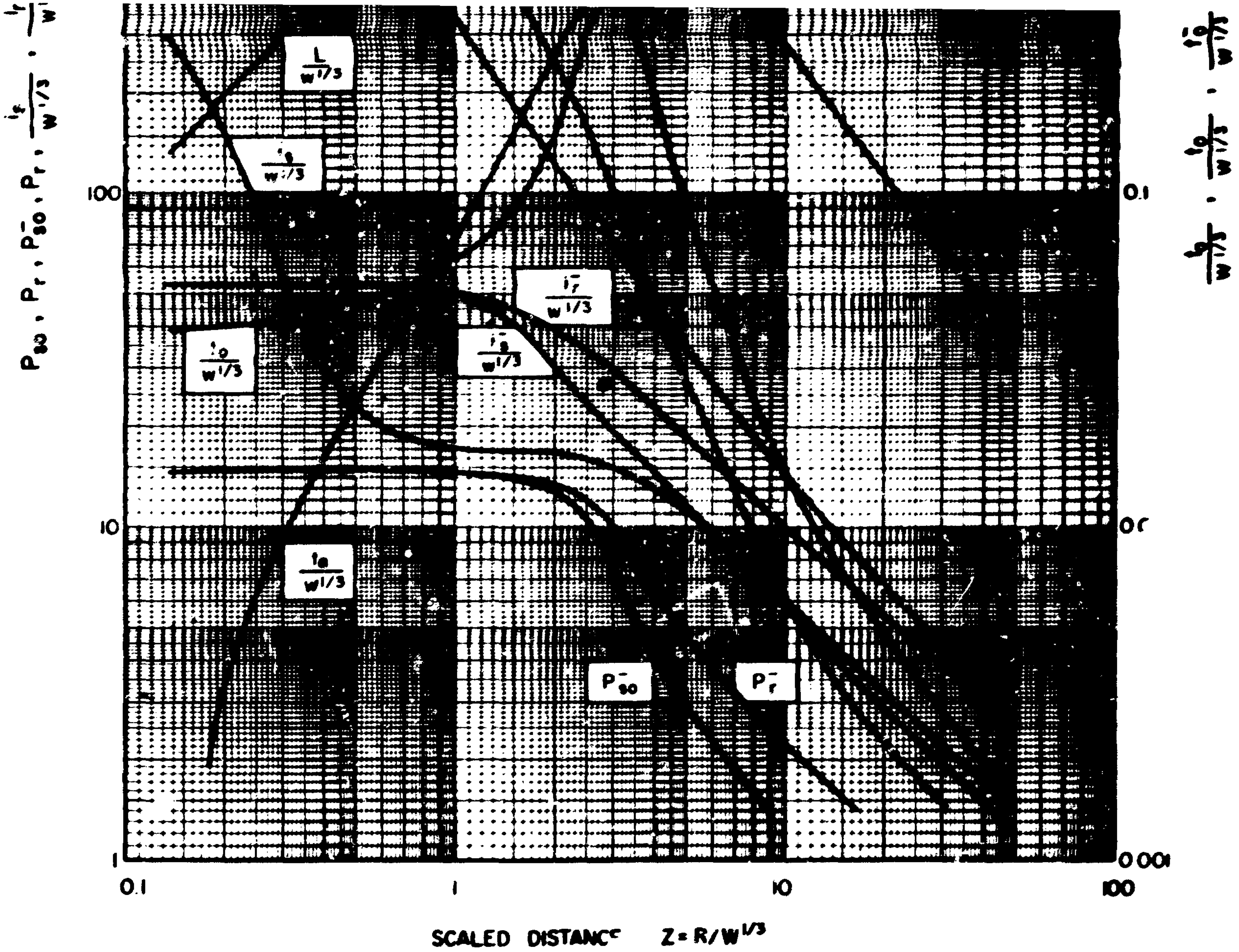


BLAST LOADING CATEGORIES		
Charge Confinement	Category	Protective Structure
Unconfined	1. Free Air Burst Loads 2. Air Burst Loads 3. Surface Burst Loads	Shelter
Confined	4. Exterior or Leakage Pressure Loads	Shelter
Confined	5. Interior or Close-in Blast Loads	Cubicle or Barrier

Figure 4 BLAST LOADING CATEGORIES

A


REF 4-1 & 4-3
100,000
10,000
1000
100
10
1
U
Pr
to/W1/3
Pso
Lw/W1/3
ir/W1/3
L
ir/W1/3 , is/W1/3 , tr/W1/3
to/W1/3 , Lw/W1/3 , Lw/W1/3 , U, u



P_{so} = Peak Positive Incident Pressure, psi	$t_o/W^{1/3}$ = Scaled Positive Duration of Positive Phase, ms/lb$^{1/3}$
P^-_{so} = Peak Negative Incident Pressure, psi	$t_o^-/W^{1/3}$ = Scaled Negative Duration of Positive Phase, ms/lb$^{1/3}$
P_r = Peak Positive Normal Reflected Pressure, psi	$L_w/W^{1/3}$ = Scaled Wave Length of Positive Phase, ft/lb$^{1/3}$
P^-_r = Peak Negative Normal Reflected Pressure, psi	$L_w^-/W^{1/3}$ = Scaled Wave Length of Negative Phase, ft/lb$^{1/3}$
$i_s/W^{1/3}$ = Scaled Unit Positive Incident Impulse, psi-ms/lb$^{1/3}$	U = Shock Front Velocity, ft/ms
$i_s^-/W^{1/3}$ = Scaled Unit Negative Incident Impulse, psi-ms/lb$^{1/3}$	u = Particle Velocity, ft/ms
$i_r/W^{1/3}$ = Scaled Unit Positive Normal Reflected Impulse, psi-ms/lb$^{1/3}$	W = Charge Weight, lbs
$i_r^-/W^{1/3}$ = Scaled Unit Negative Normal Reflected Impulse, psi-ms/lb$^{1/3}$	R = Radial Distance from Charge, ft
$t_A/W^{1/3}$ = Scaled Time of Arrival of Blast Wave, ms/lb$^{1/3}$	Z = Scaled Distance, ft/lb$^{1/3}$

Figure 5 SHOCK WAVE PARAMETERS FOR SPHERICAL TNT EXPLOSION IN FREE AIR AT SEA LEVEL

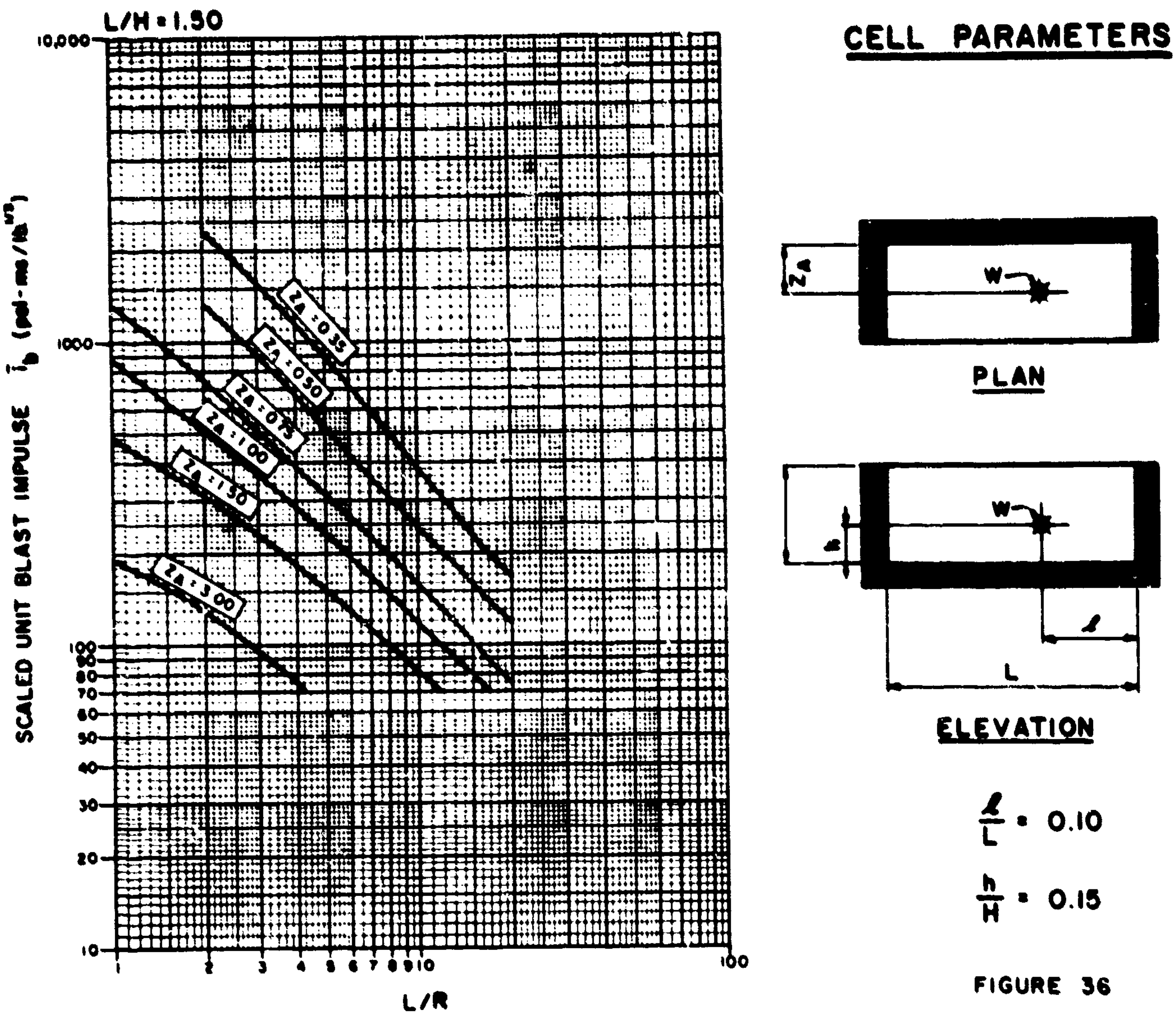


Figure 6 Typical Impulse Chart

BLANK PAGE

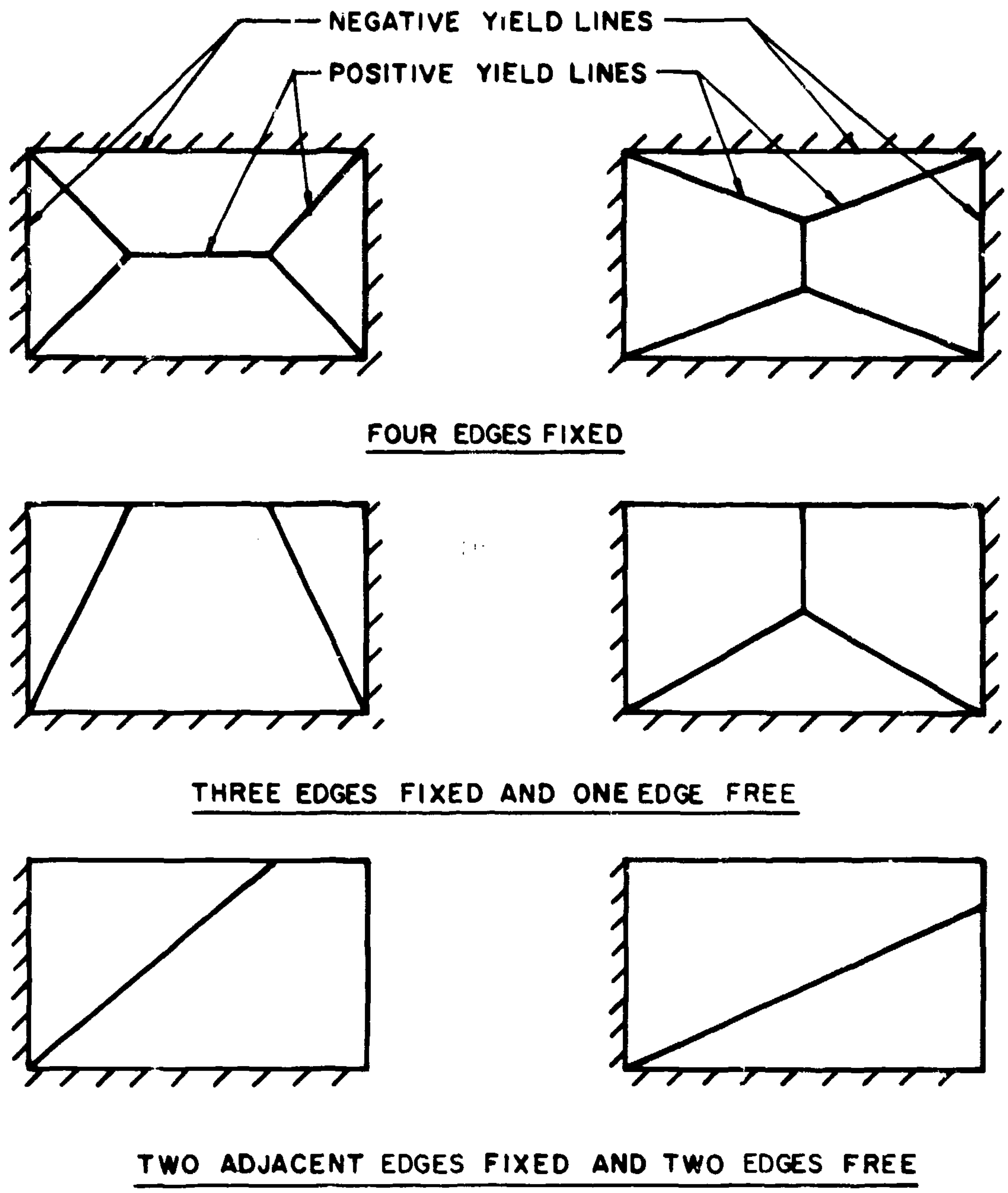


Figure 7 IDEALIZED YIELD-LINE LOCATIONS FOR SEVERAL TWO-WAY ELEMENTS

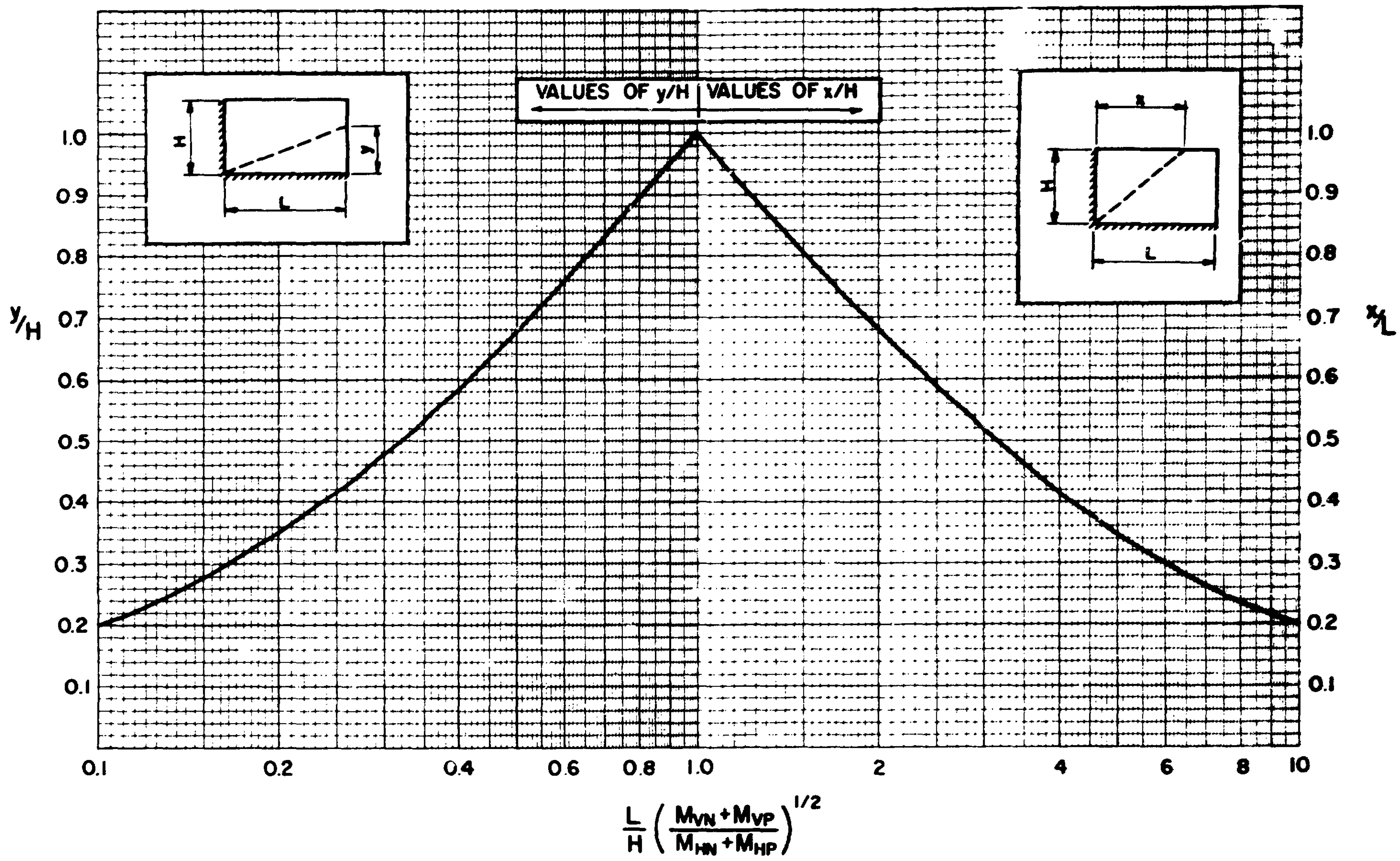


Figure 8 YIELD LINE LOCATION FOR TWO-WAY ELEMENT WITH TWO ADJACENT EDGES FIXED AND TWO EDGES FREE

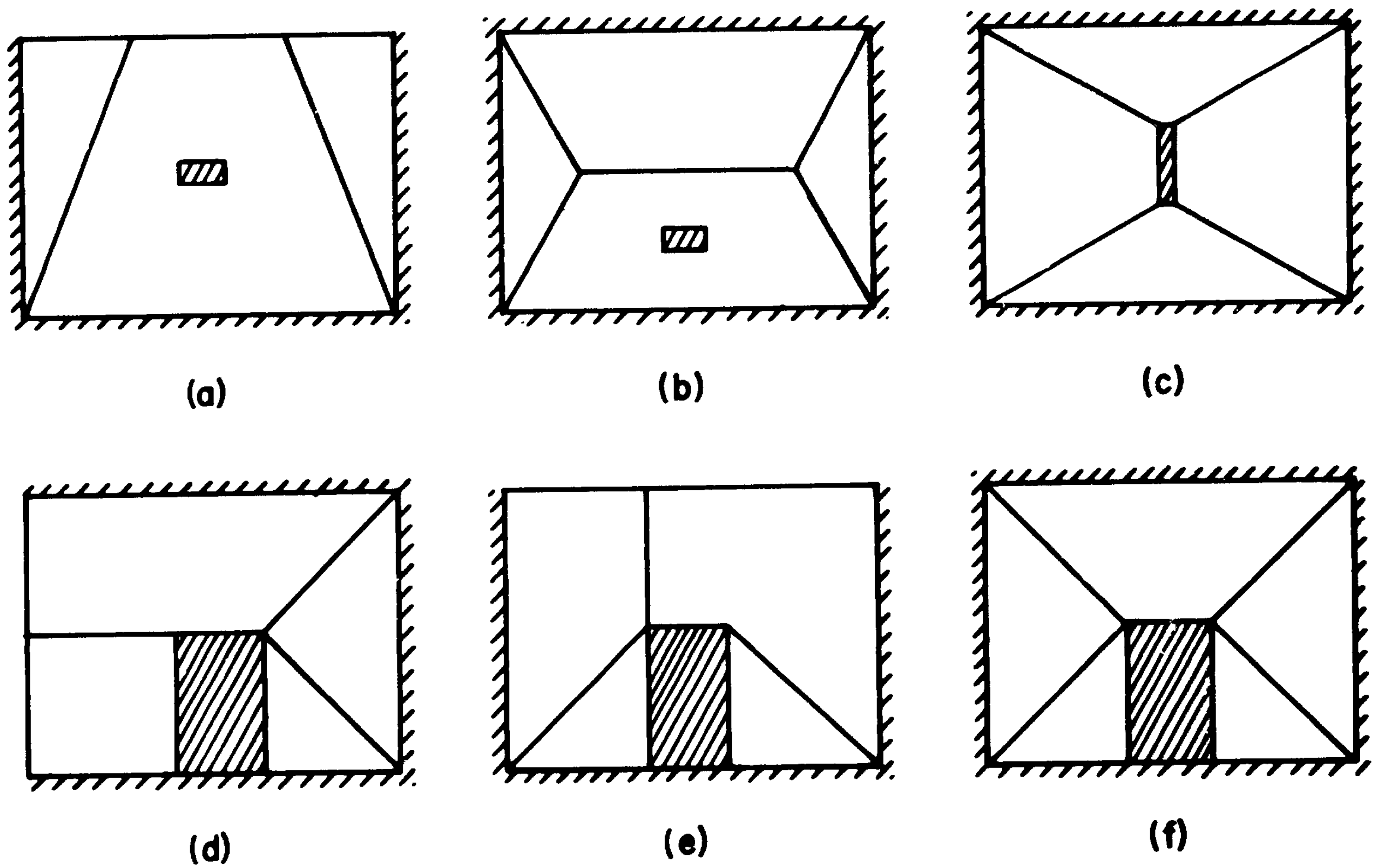


Figure 9 EFFECTS OF OPENINGS ON YIELD LINE LOCATIONS

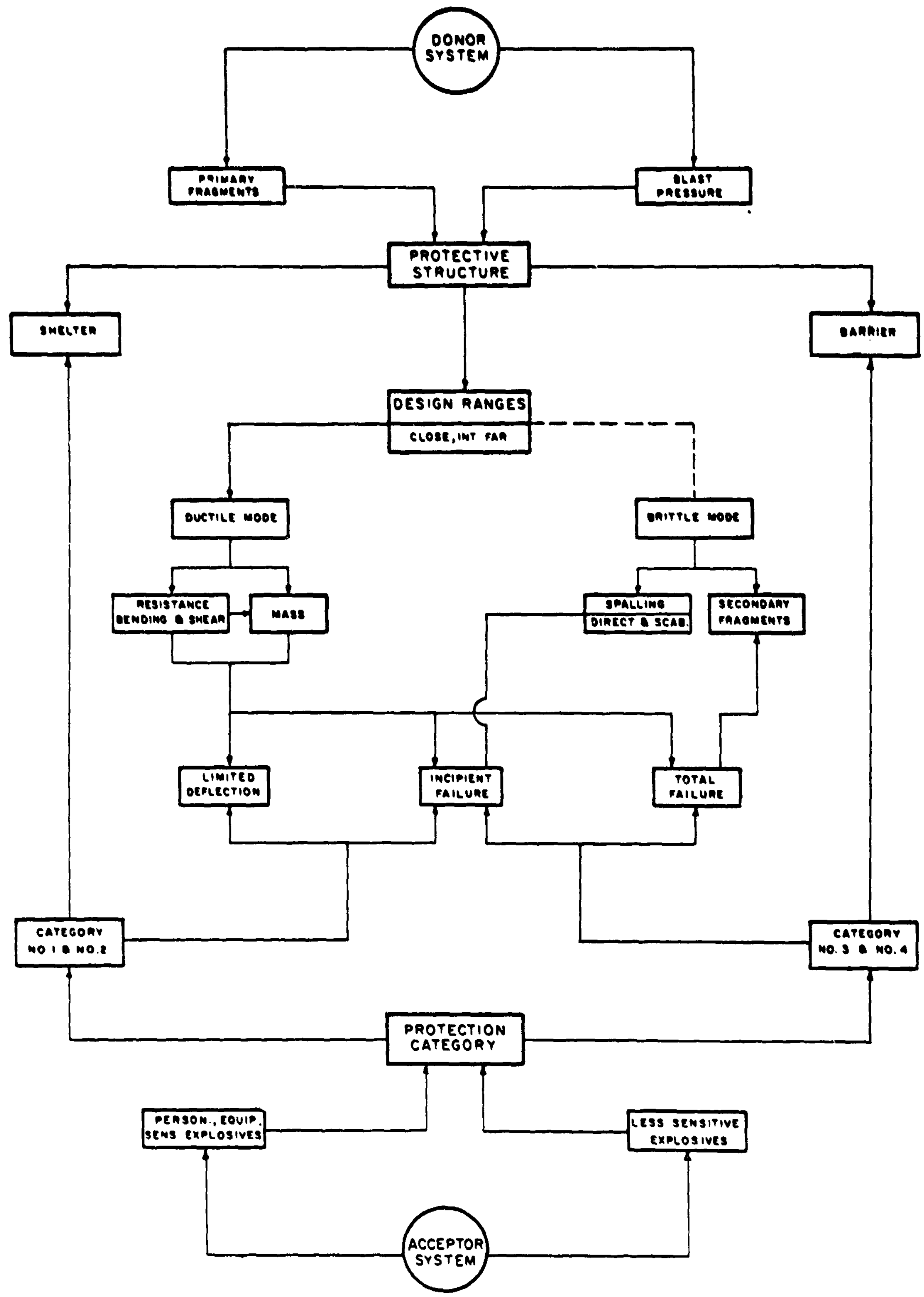


Figure 10 DESIGN PROCEDURE FOR EXPLOSIVE PROTECTIVE STRUCTURES

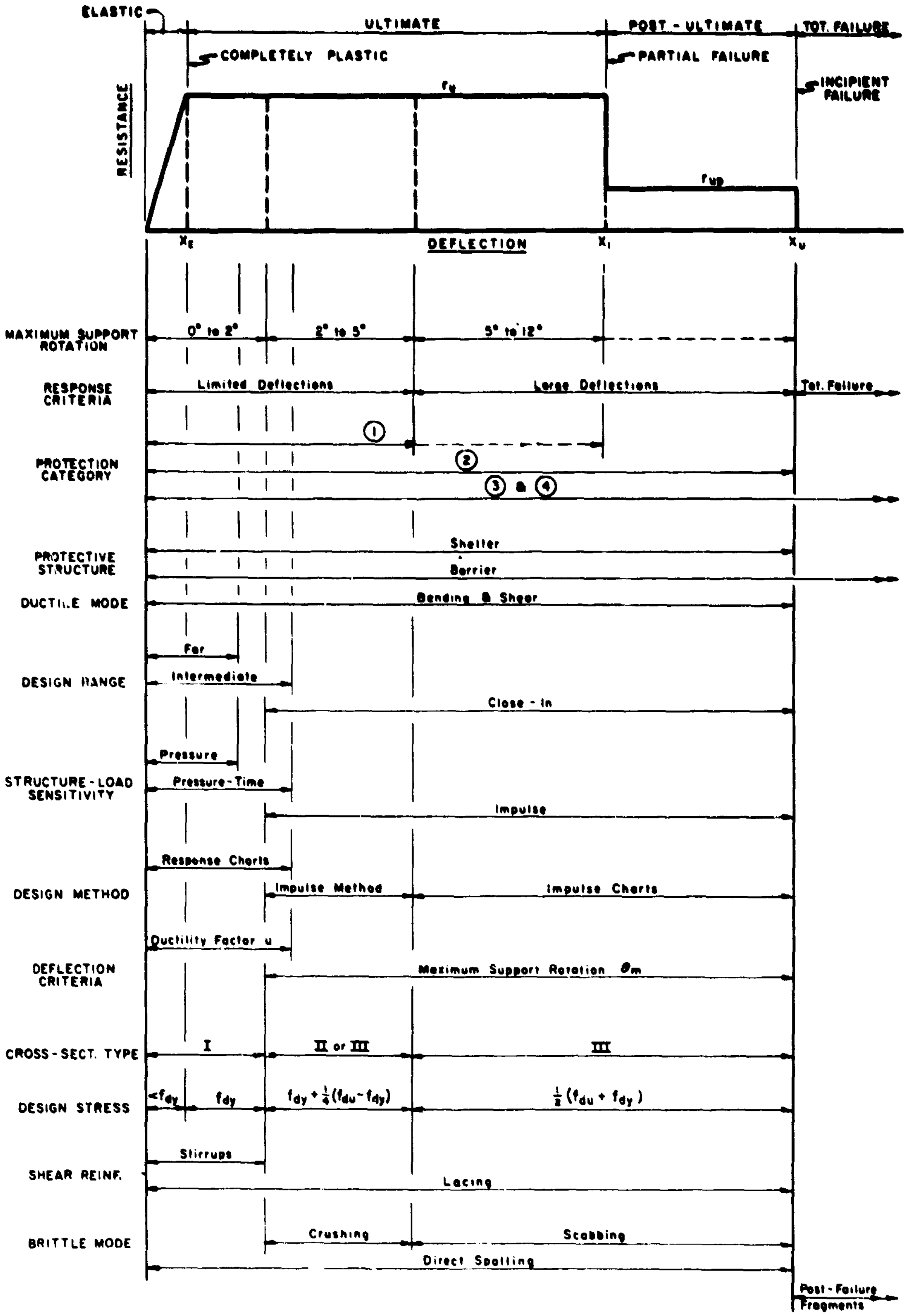


Figure 11 RELATIONSHIPS BETWEEN THE DESIGN PARAMETERS

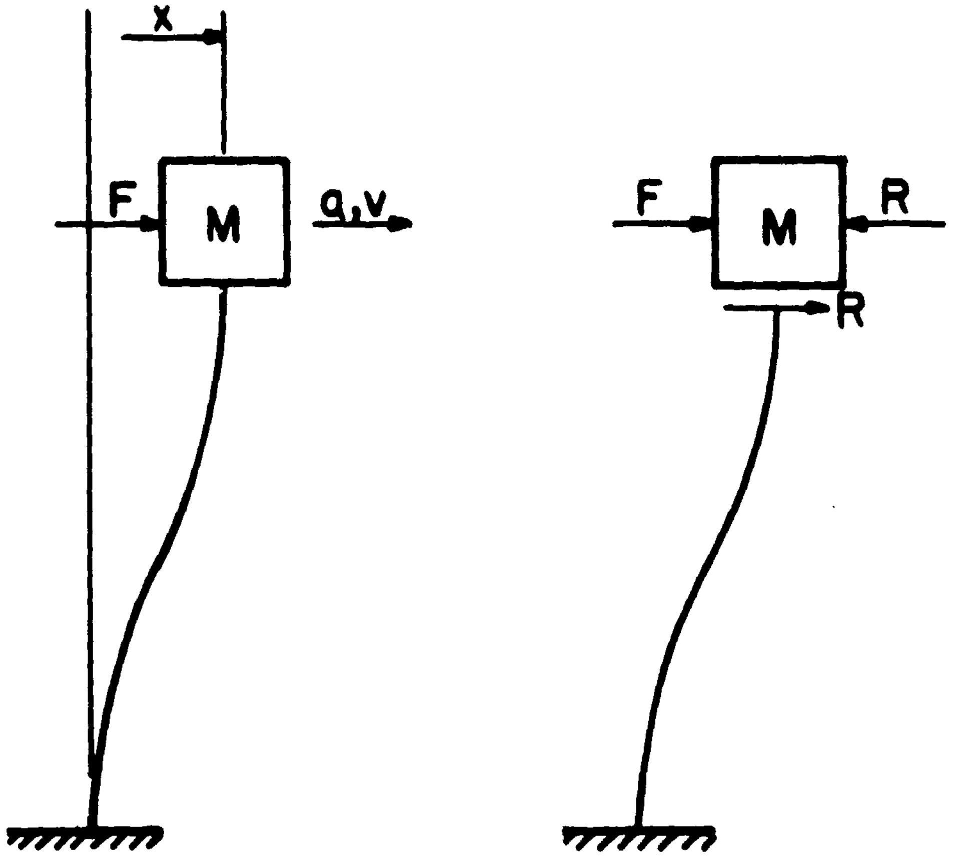
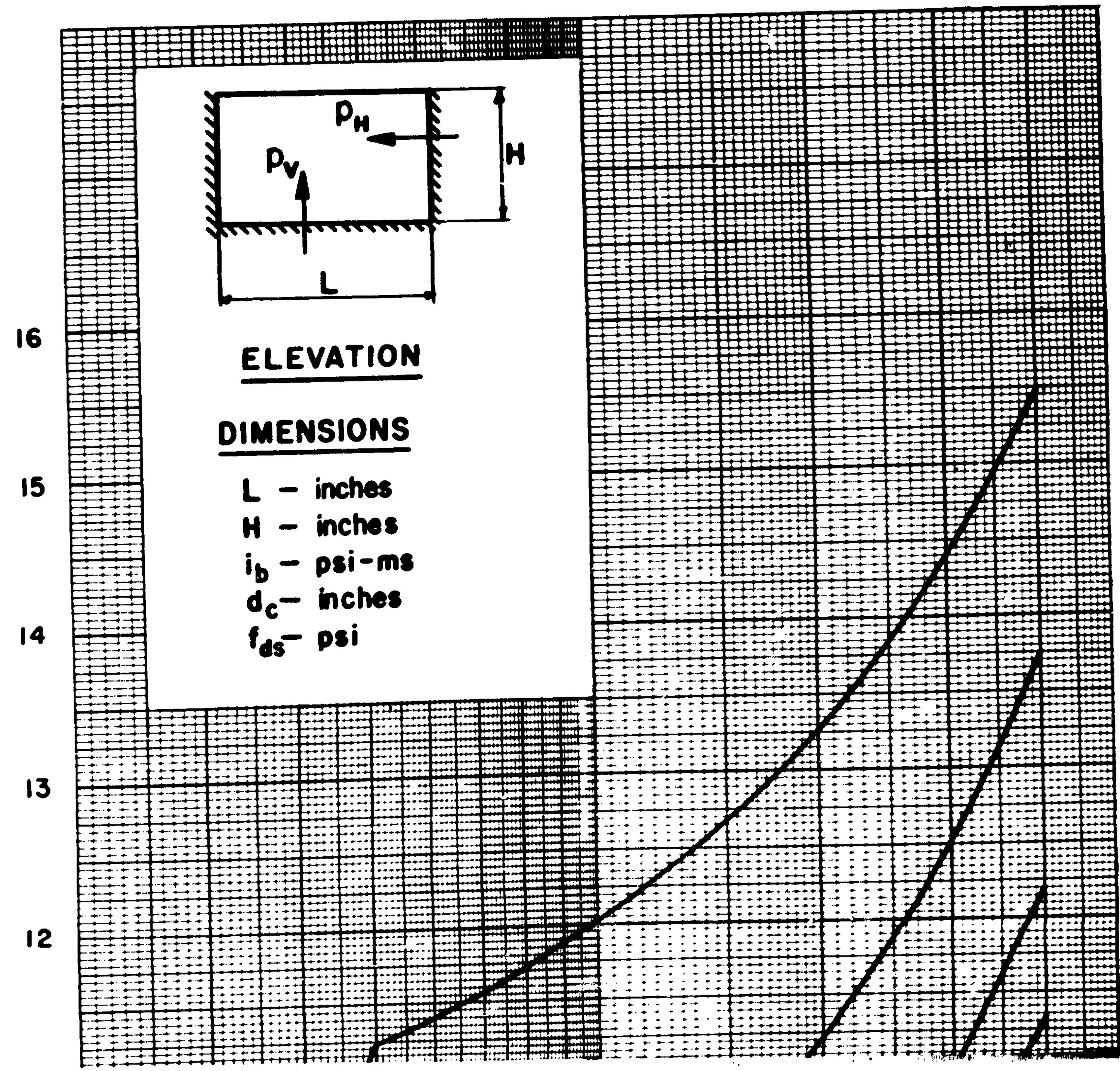
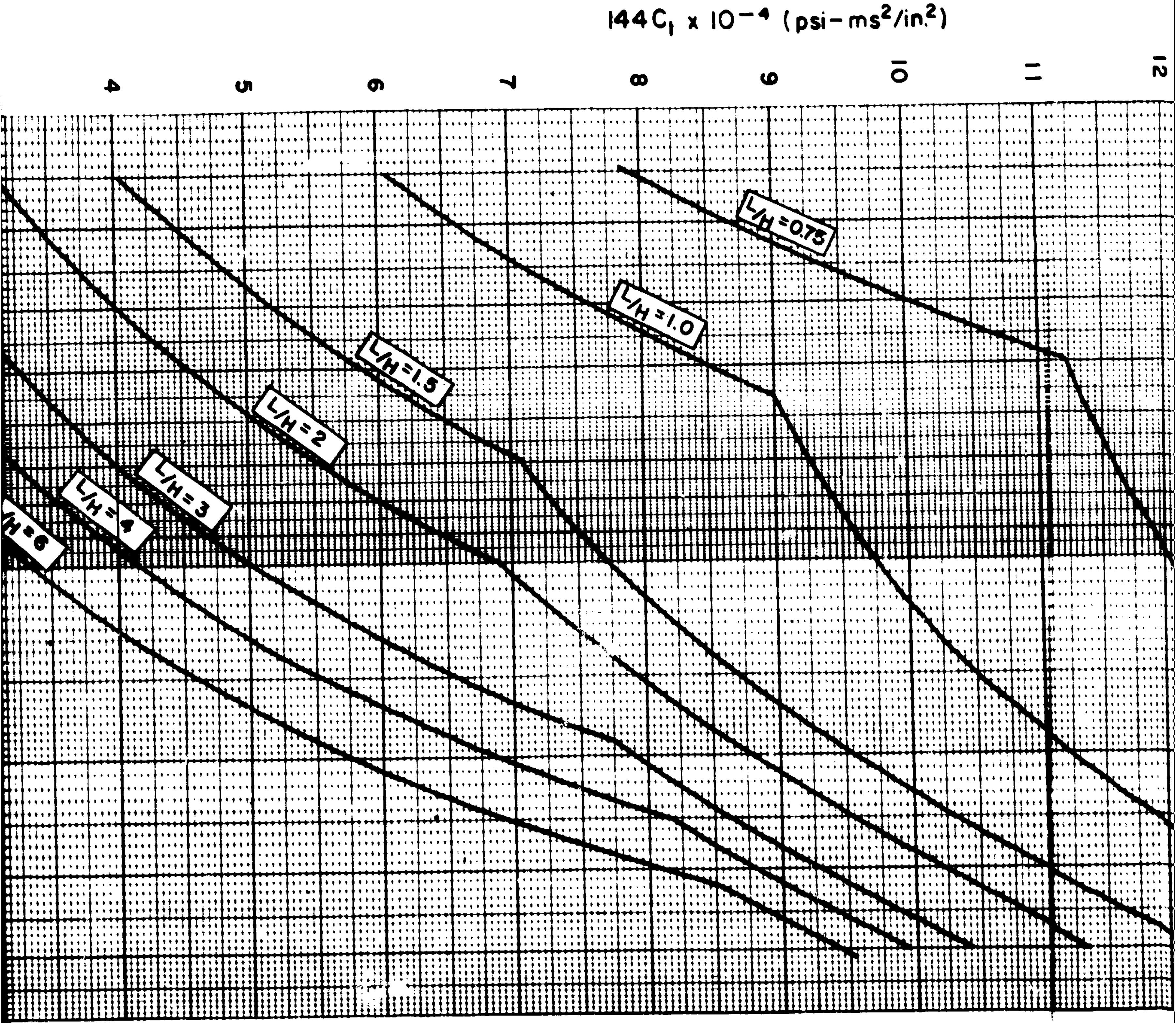


Figure 12 **TYPICAL SINGLE-DEGREE-OF-FREEDOM SYSTEM**

A



p_H
p_V
H
L
ELEVATION
DIMENSIONS
L - inches
H - inches
i_b - psi-ms
d_c - inches
f_{ds} - psi
16
15
14
13
12


144C1 x 10-4 (psi-ms2/in.2)
4
5
6
7
8
9
10
11
12
L/H=0.75
L/H=1.0
L/H=1.5
L/H=2
L/H=3
L/H=4
L/H=6

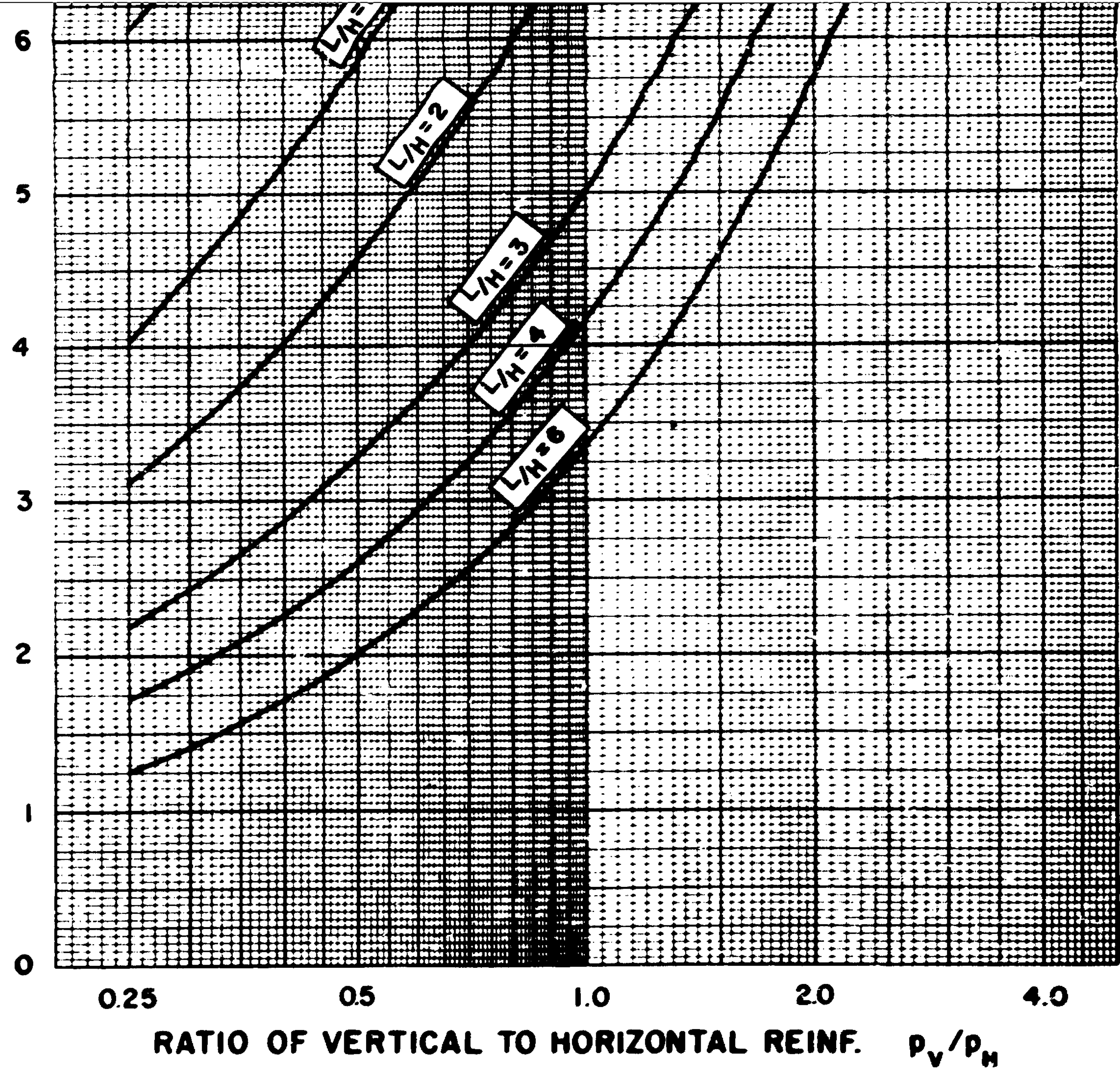


Figure 13 IMPULSE COEFFICIENT C_1 FOR AN ELEMENT WITH THREE EDGES FIXED AND ONE EDGE FREE

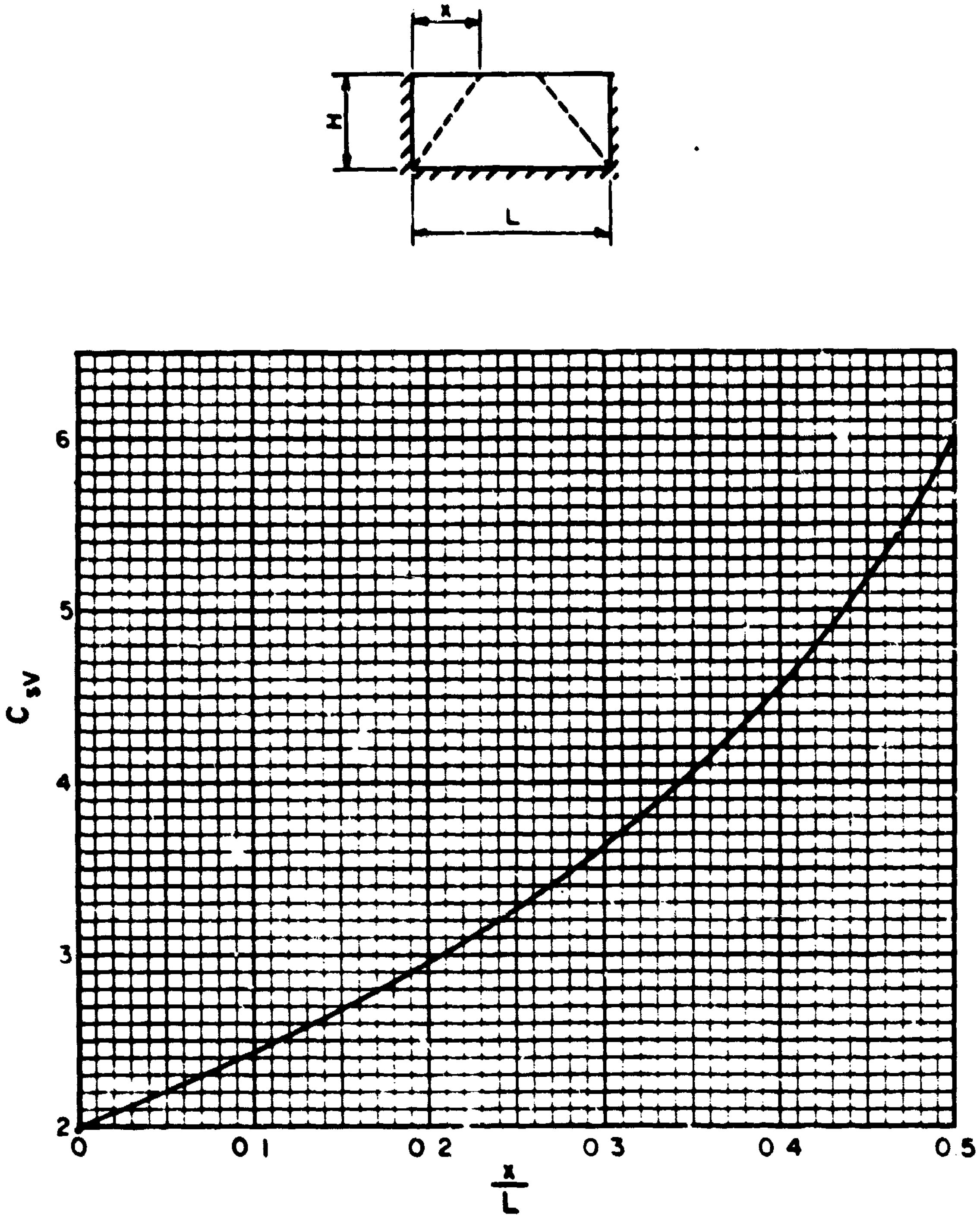


Figure 14 **SHEAR COEFFICIENTS FOR ULTIMATE SUPPORT SHEAR (CROSS SECTION TYPE II AND III)**

Figure 15 DIRECT SPALLED PANEL

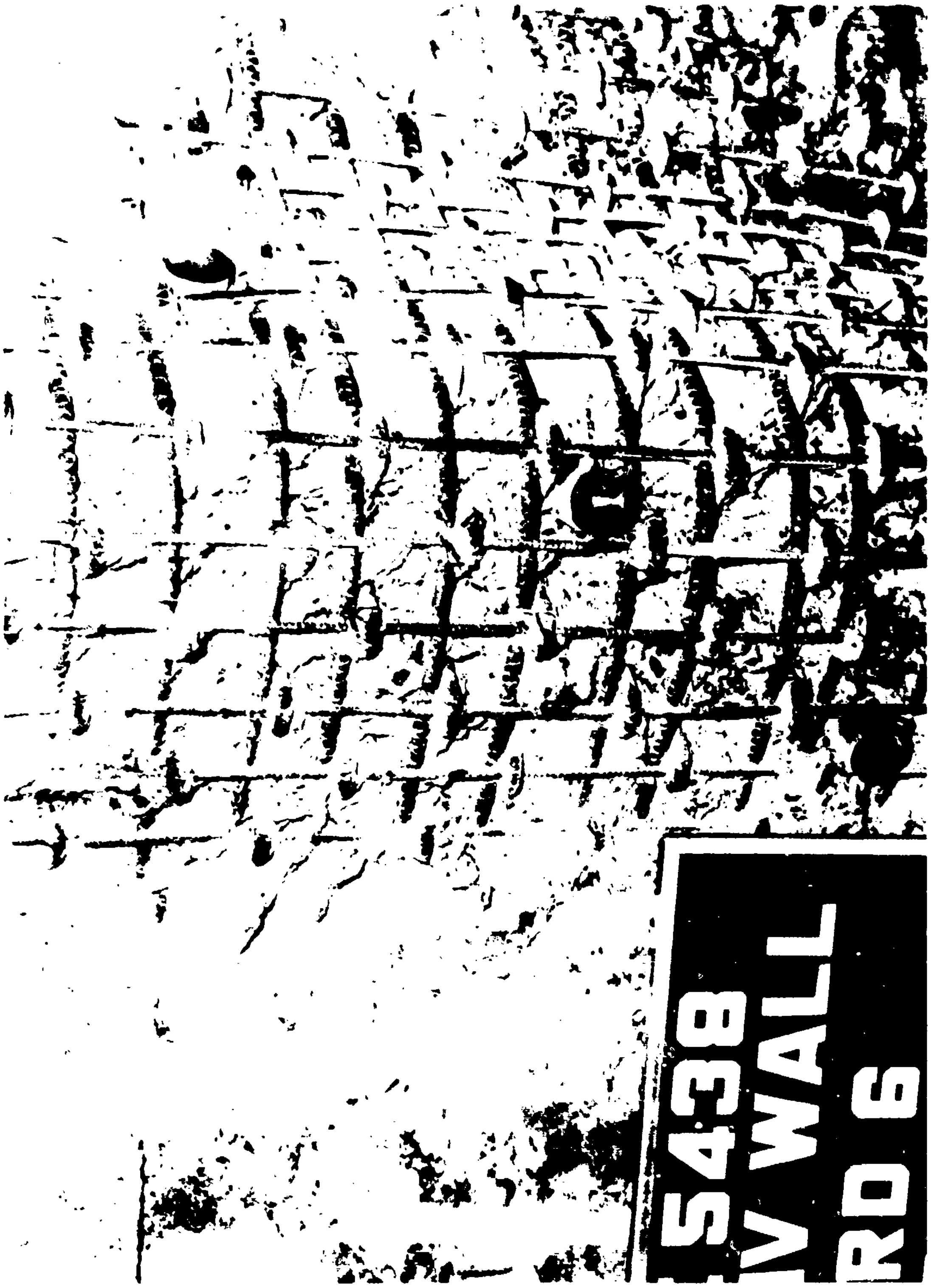


Figure 16 SCABBED PANEL

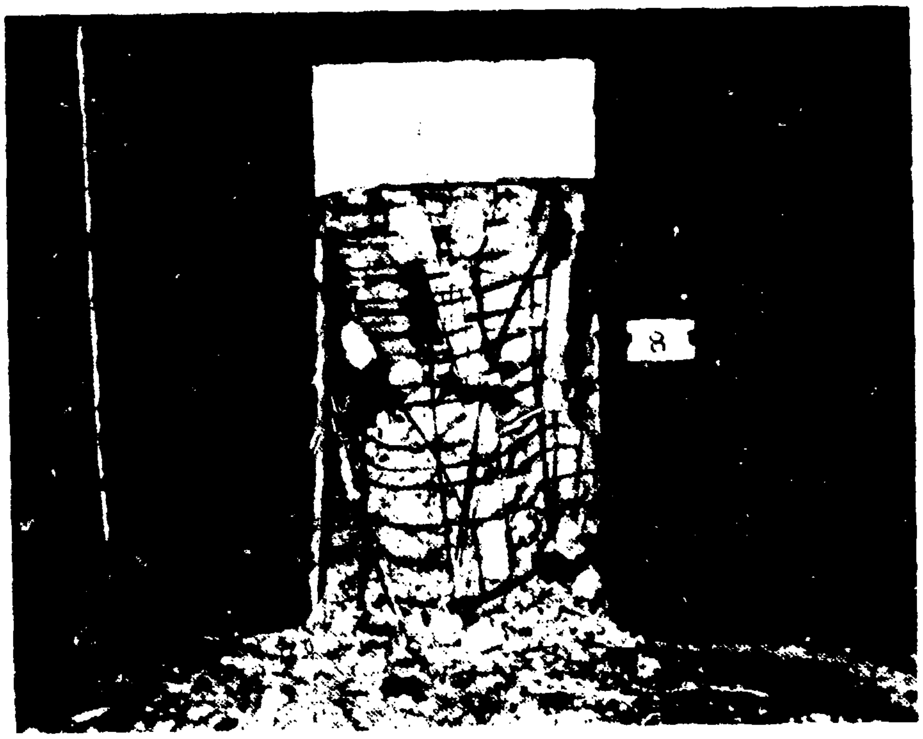


Figure 17 FAILURE OF AN UNLACED ELEMENT

Figure 18 FAILURE AT PLASTIC HINGES OF LACED MEMBER

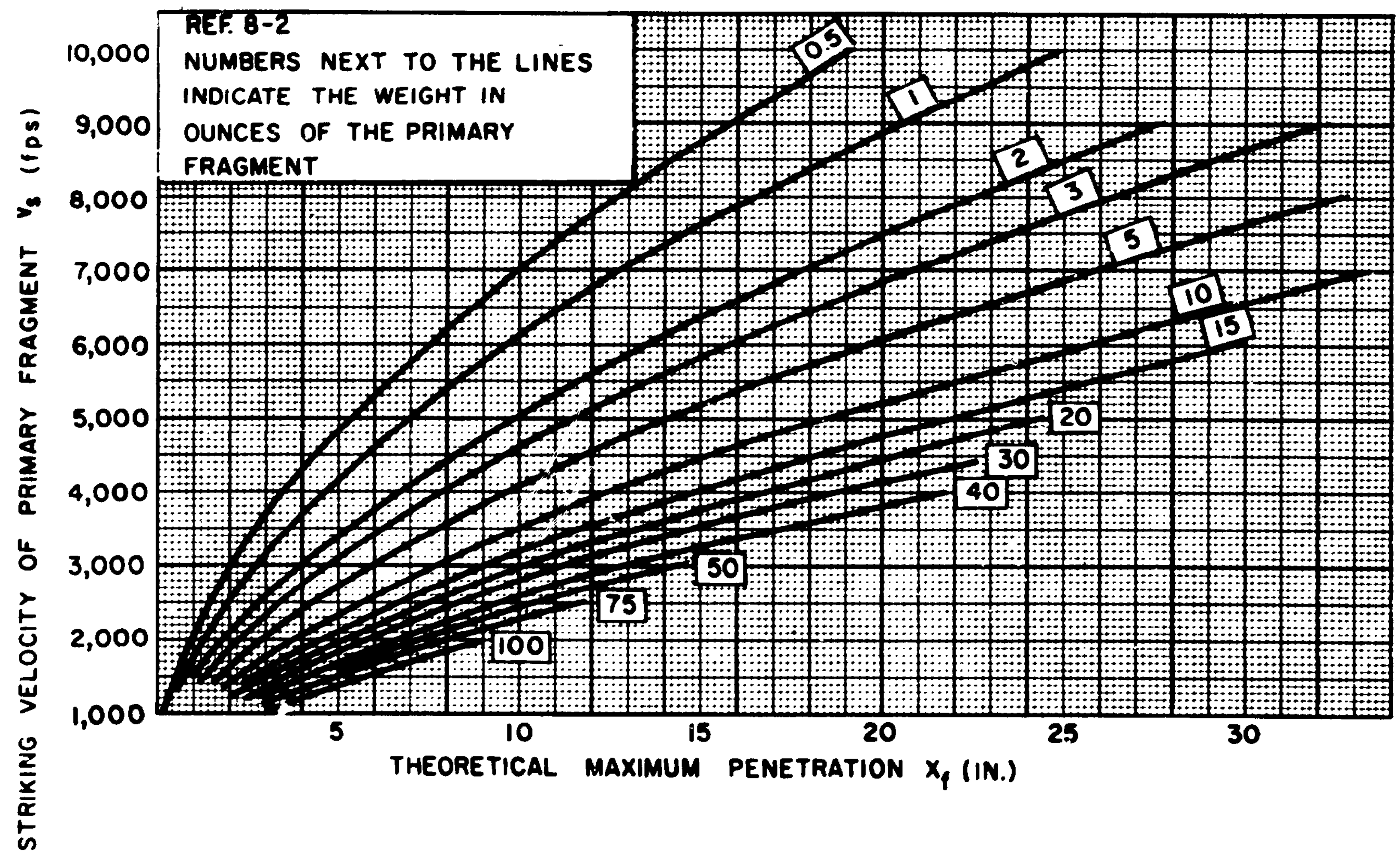


Figure 19 **FRAGMENT PENETRATION THROUGH CONCRETE**

Values of Metal Hardness Constant (k)

Type of Metal	Constant (k)
Armous Piercing Steel	1.0
Mild Steel	0.7
Lead	0.5
Aluminum	0.3

Figure 20

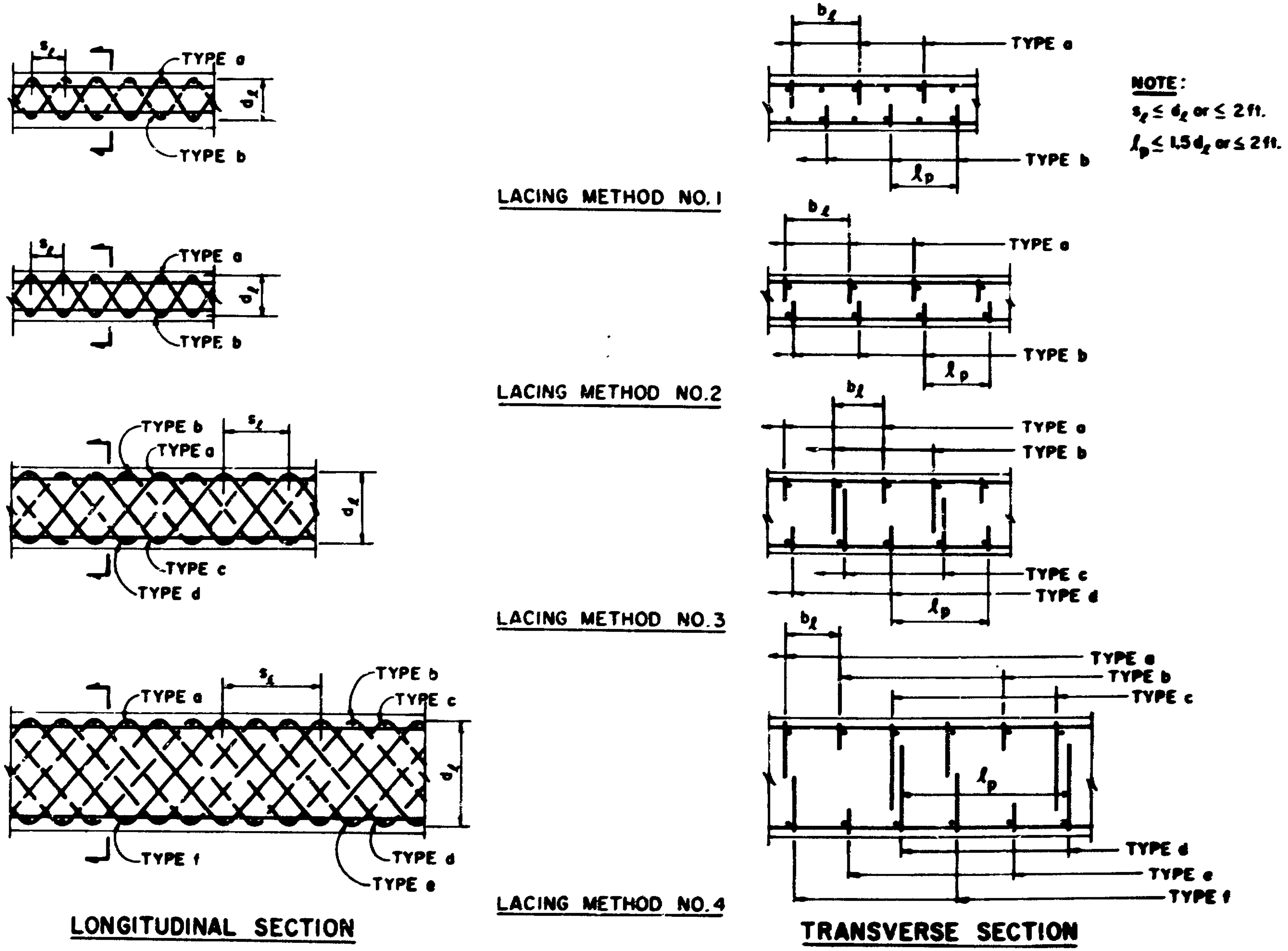


Figure 21 TYPICAL METHODS OF LACING

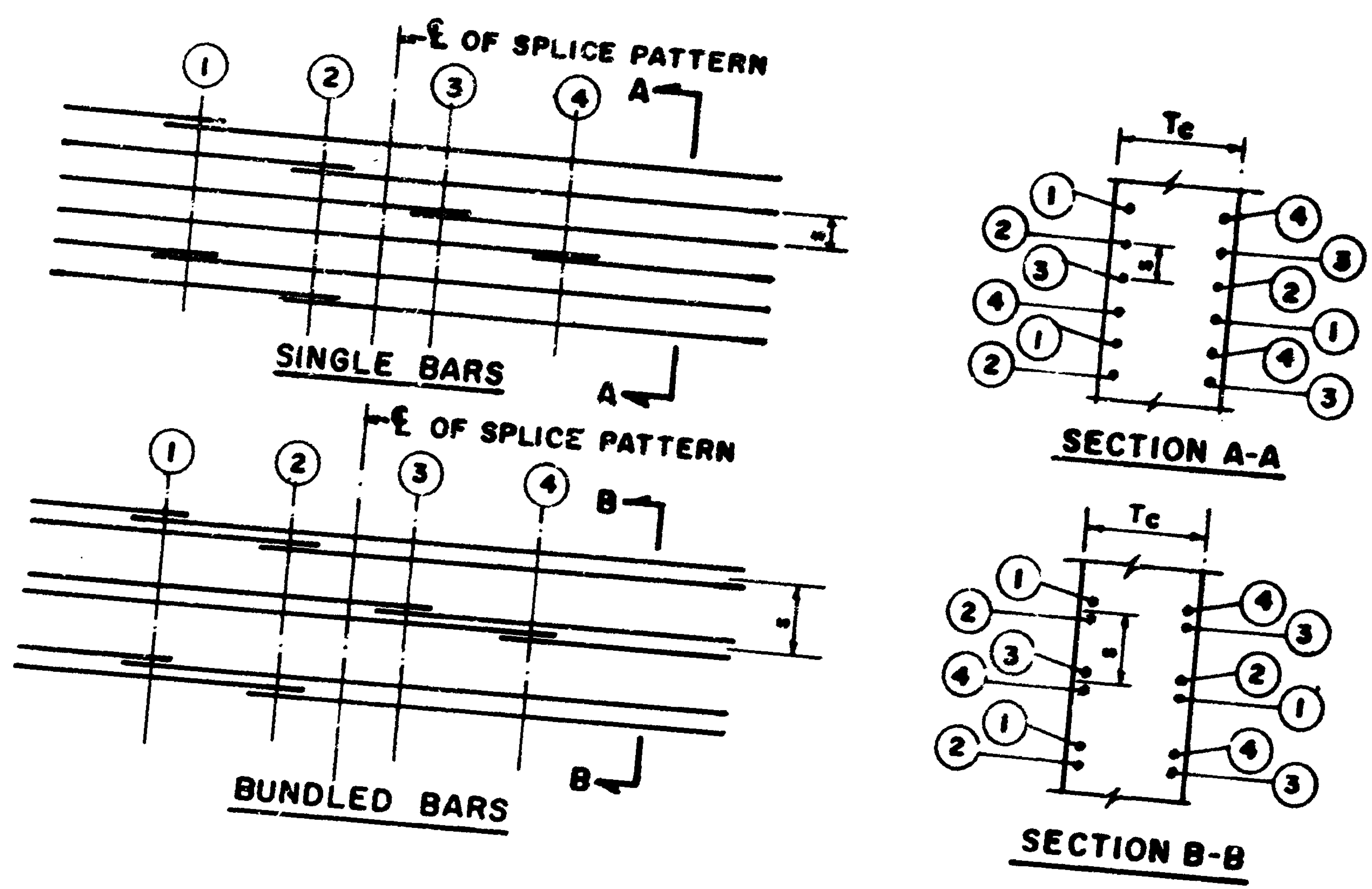


Figure 22 TYPICAL FLEXURAL REINFORCEMENT SPLICE PATTERNS

Items To Be Considered in the Design Of Protective Structures

a) Site planning to achieve safe and operationally efficient facility

b) Cost effectiveness to achieve economical design of both protective structures and overall layout of facility

c) Proper location and arrangement of entranceways and methods of closures for openings in shelters

d) Protection against structure motion

Figure 23

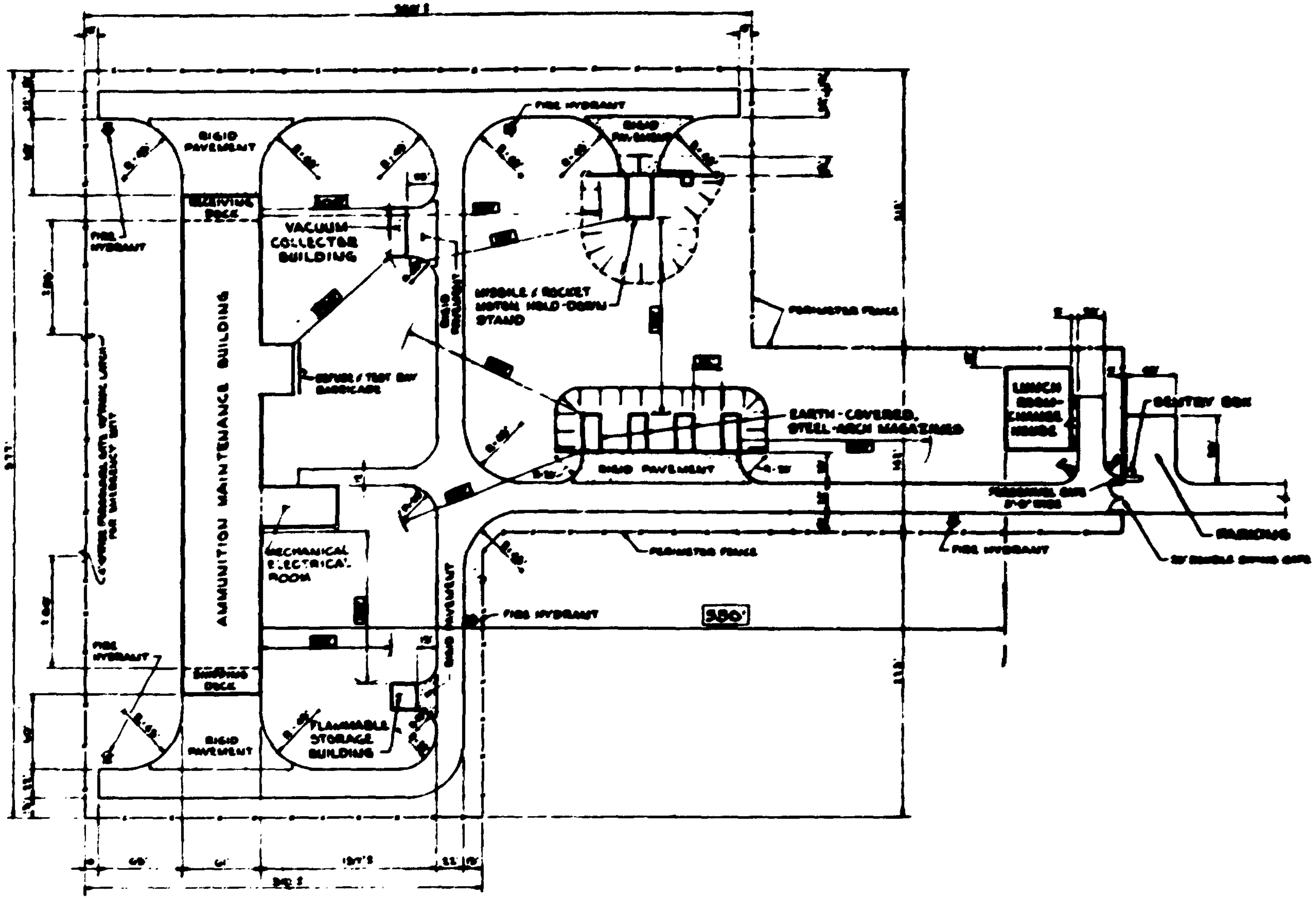


Figure 24 SITE PLANNING OF TYPICAL AMMUNITION MAINTENANCE FACILITY

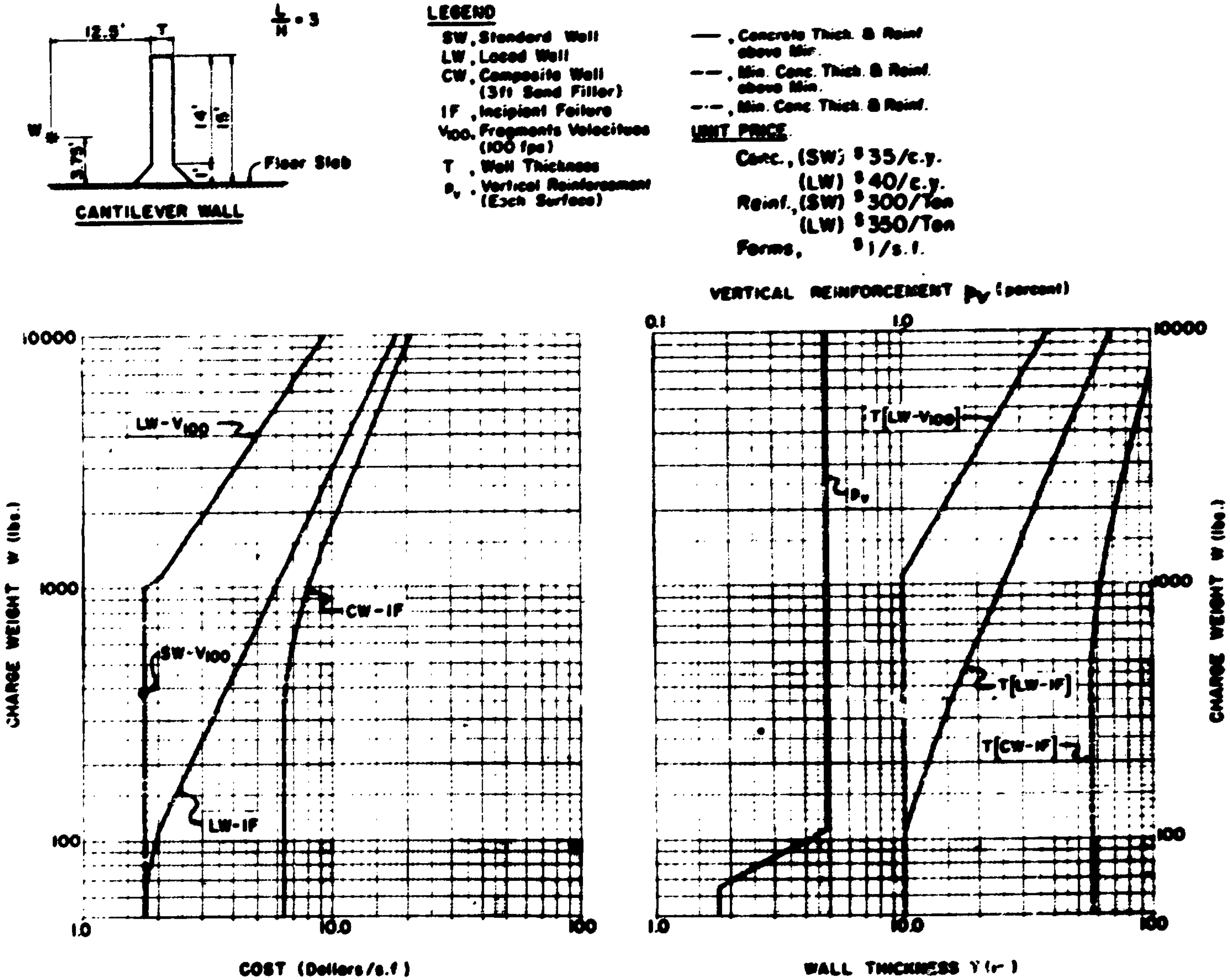


Figure 25 COST ANALYSIS OF LACED CANTILEVER WALL

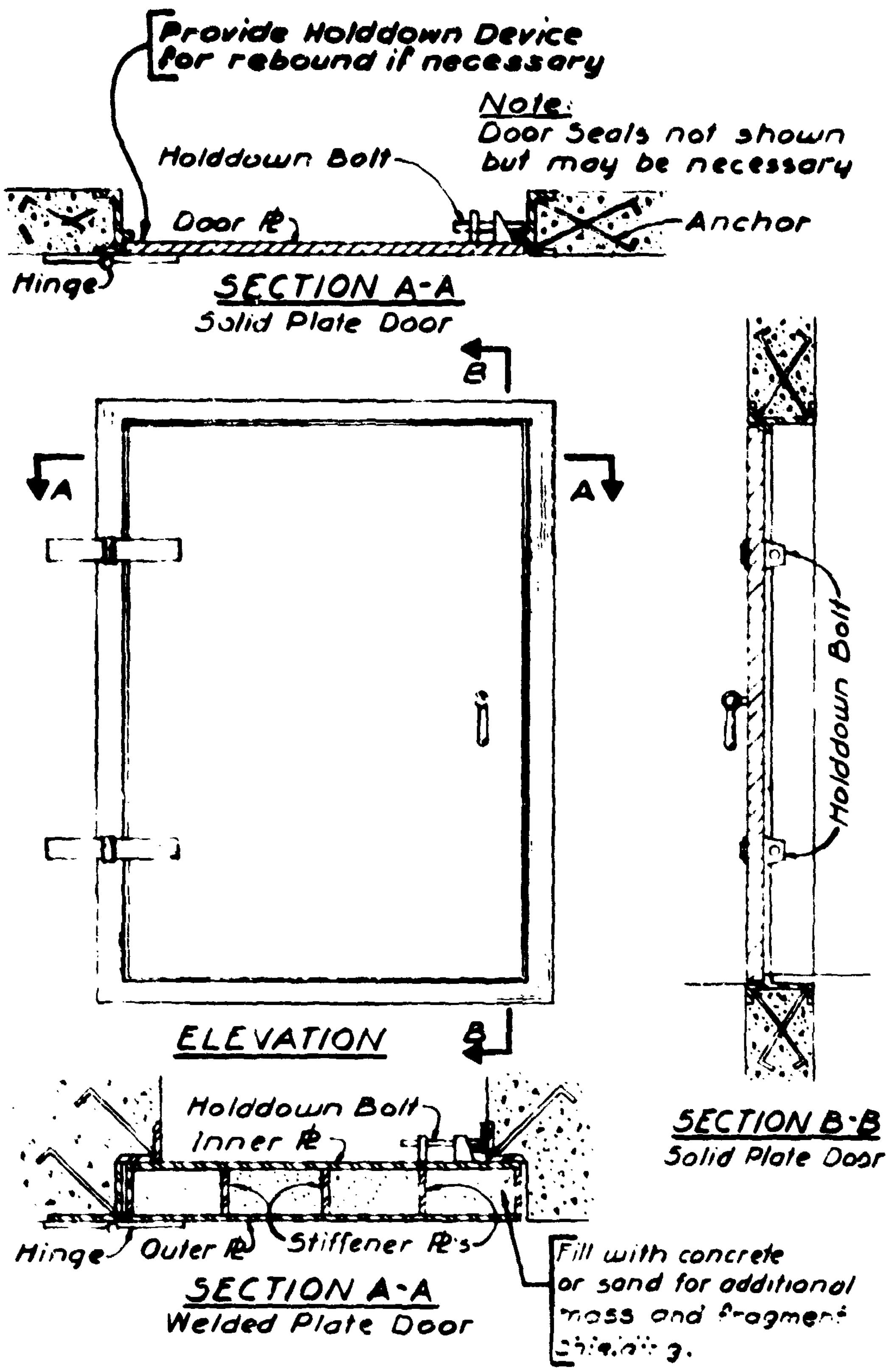


Figure 26 STEEL PLATE DOORS

NAVY EXPLOSIVES SAFETY PROGRAM

by

Herbert M. Roylance
Naval Ordnance Systems Command
Washington, D. C.

We had hoped that at this meeting we would be able to brief you on some of the details of the ORISKANY and FORRESTAL accidents which I am sure you have all read about in the newspapers; however, the reports of the Boards of Investigation are not yet releasable. I can, however, discuss very briefly and generally, the basic causes of these accidents, and the resulting reorganization for safety in the Navy.

Although different weapons were involved, the basic reason for the accidents was a combination of several factors, not the least of which, was the extreme tempo of operations in the WestPac area. Also involved were personnel deficiencies, and to some degree, design deficiencies in the weapons involved. The immediate instrument in the case of the ORISKANY fire was a MK 24 aircraft parachute flare which was inadvertently ignited on the deck and communicated to other flares in the area. The apparent immediate cause of the FORRESTAL accident was a weapon malfunction. You all know the final results from the newspaper and magazine articles which followed.

As might be expected, as a result of these accidents, there were numerous studies and investigations concerned with the Navy's overall safety program, and there was considerable upgrading at all levels. In brief, the Office of the Assistant Chief of Naval Operations (Safety) was established. To assist, a Navy Safety Center was established at Norfolk with the existing Aviation Safety Center serving as the nucleus. While the organization of this Center is not yet firm, it will essentially concern itself with operational safety and will be the depository for all accident/incident reporting and analysis. It will also provide an investigative capability for use as required. The basic division of functions will be along operational lines and will provide for four major divisions, which are parallel to those of the ACNO (Safety). They will be aviation, submarine, surface ship and shore activities. The line divisions will be supported by the usual staff, including an ordnance division. As of now, the aviation function is staffed as is the submarine division, which moved from New London where the Submarine Safety Center was previously located. It is anticipated that the explosive accident/incident reporting system, which is now computerized at the Naval Weapons Laboratory, Dahlgren, and which will be discussed in one of the specialist sessions, will be relocated to the Safety Center at Norfolk and will be consolidated into one reporting system.

You will remember that I stated that the organization in the Chief of Naval Operations was for the purpose of coordinating the entire safety program. Certain of the technical aspects of the safety programs or component programs, if you will, have been delegated to the Chief of Naval Material, who in turn has redelegated to the Systems Commands. The Explosive Safety Component Program is assigned to the Naval Ordnance Systems Command. In his delegation to the Naval Ordnance Systems Command, the Chief of Naval Material states 14 distinct areas of responsibility. I will not discuss all 14 of these in detail; however, the first 2 items are basic and provide the foundation for the others. They are (1) formulate overall policy for the explosives safety program and provide professional guidance concerning weapons, weapon systems, and explosive material throughout the Department of the Navy in the complete life cycle from research and development to ultimate use or disposal; and (2) establish, promulgate, and implement appropriate explosives safety regulations, instructions, publications, guidance, and procedures applicable to the areas mentioned.

These tasks are briefed in the Naval Ordnance Systems Command organization manual as follows:

Technical Authority, Guidance and Assistance. In addition to providing other technical guidance and assistance as appropriate in connection with its assigned material support responsibilities, the Naval Ordnance Systems Command is the single technical authority for explosives safety. The Naval Ordnance Systems Command will be the single point of contact within the Naval Material Command on explosives safety matters to the extent required to act authoritatively for the Naval Material Command on such technical matters. This responsibility includes policy formulation for the Chief of Naval Material and executive direction to the extent delegated or specified by the Chief of Naval Material. (Explosives safety, as used in this article, includes conventional as well as nuclear component explosives safety.)

In order to carry out the above basic tasks, we have organized the Safety Division in NAVORD along the following lines: (1) Explosives Safety - This Branch insures the implementation of the Ordnance Systems Command's Explosive Safety Program, including establishing, promulgating and implementing appropriate explosive safety regulations, instructions, publications, guidance, and procedures within the Naval establishment. This Branch is akin to the explosive safety function which has been carried out by all Services for many years and includes storage, transportation, production and disposal. The second Branch is Systems Safety Engineering. Its mission is to translate military operational systems requirements into safety engineering plans and policies to be pursued by the Ordnance Systems Command in meeting safety requirements; direct the management of a consolidated system safety program established to ensure that safety is engineered into weapon systems; direct the management of a comprehensive development test and evaluation program to provide system safety

engineering policy requirements, criteria and regulations for implementation by Ordnance Systems Command throughout the Naval establishment; direct the management of a comprehensive exploratory and supporting research program to enhance future readiness by disclosing and resolving previously unknown or unforeseen safety hazards relative to all Navy weapons systems.

In order to implement this aspect of the Explosives Safety Program, the Weapons Systems Safety Review Board has been established. This Board is chaired by the Director of the Safety Division and its membership is one representative from each systems command plus representation from OPNAV and NAVMAT.

I want to emphasize that neither the Safety Division nor the Review Board accomplishes all of these tasks on their own. We consider that it is the responsibility of the respective program or project manager to arrange for the preparation of the safety sections of their technical development plans, safety test plans, and for the conduct of the safety tests. The Weapons Systems Safety Review Board will then analyze the results of the tests as well as the design of the system to ensure that adequate safety is incorporated, and when so assured, will certify the weapon system to the appropriate systems commander for release to production and service use. The third branch concerns itself with the hazards of electromagnetic radiation to ordnance, for which we use the acronym 'HERO'. Its mission is to serve as central point of contact for Navy HERO matters and be responsible for overall HERO policy, technical procedures and criteria. Establish requirements for the application of uniform practices and techniques for the purpose of reducing the adverse susceptibility of all weapons and weapon systems to electromagnetic radiation; provide for test and evaluations of new and advanced electronic techniques and practices as they are applicable to HERO; determine the need for and assure that there are appropriate programs for applied research and development directed toward reduction of hazards of weapons; plan and direct the hazards of electromagnetic radiation to ordnance (HERO) program including determination and evaluation of weapon susceptibility to radiation hazards.

Inasmuch as HERO is many times a prime suspect as the cause of explosive accidents, we have embarked on a program, with the aircraft carriers as first priority, of conducting HERO surveys on all ships where electromagnetic radiation might create a problem and in addition, similar surveys will be made at a number of shore activities which handle unpackaged or HERO susceptible weapons.

We have two basic research and development programs related to systems safety engineering and HERO. The one concerned with systems safety involves the development of safety sections of PTA's and TDP's, material for systems safety manuals and safety specifications. One aspect of this program is development of a mathematical model by which a safety

index can be determined for a particular weapons system. The first phase of this project has been completed and it appears feasible. We are now embarking on the further development of the system.

The basic objective of the HERO R&D program is ultimately to eliminate the necessity for HERO restrictions aboard ship and by this I mean, the control of RF emissions during ordnance handling through the provision of fixes for existing weapons and the development of HERO-safe designs for future weapons. This objective is being reached in part through publication of the so-called RADHAZ Manual, a HERO design guide and a HERO specification.

To assist us in carrying out these functions, a small group at the Naval Weapons Laboratory, Dahlgren, provides services, particularly in the R&D area. It is anticipated that further field activity support will be required but the exact location has not yet been determined.

As you can well imagine, liaison with other commands, program managers and field activities primarily concerned with particular classes of weapons such as underwater, air launched and surface launched, is necessarily widespread. Liaison with the Army, Air Force, NASA, numerous contractors and research institutes, is a continuing task. All of this we consider to be essential in meeting the goal of the Navy's Explosive Safety Program. Which in simplified terms, is to prevent the accidental or inadvertent initiation of any weapon system or component thereof. How well we reach this goal, only time will tell.

A COMPENDIUM ON ELECTROSTATICS PERTAINING TO EXPLOSIVES SAFETY

by

John T. Petrick
Charles L. Berkey
U. S. Naval Weapons Laboratory
Dahlgren, Virginia

INTRODUCTION

Every day manufacturers add more synthetic fabrics and parts to their finished products. Along with these they are adding considerable electrostatic safety problems in areas where no hazard existed previously. Several methods are available to resolve these problems; however, some foresight and knowledge of electrostatics are necessary to predict that a particular product or process presents an electrostatic hazard.

It is the object of this paper to provide a basis of thought in electrostatics especially for those involved in explosives safety. Let us begin by discussing a few methods of electrostatic charge gen[illegible]ion.

ELECTROSTATIC CHARGE GENERATION

Among the prominent charge builders are contact of dissimilar materials, flowing fluids, ambient electric fields, and asymmetric friction of similar materials.

CONTACT CHARGING

Contact charging is achieved by simply touching two dissimilar objects together. Generally each object has a unique microscopic electric field at the point of contact. When contact is made, the difference in the individual fields becomes a net field in which charge carriers may travel. Figure 1 illustrates this effect by showing the voltage profile close to each object alone and the profile when contact is made. The force exerted on the charge carriers is proportional to the slope of the curves shown.(2)

After contact we see that one object receives charges of one sign and the other object, having lost these charges, is assumed to be equally charged by charges of the opposite sign.

By sliding one object over the other we may produce further charging which is attributed to the exposure of more area of contact. This point is very important since common, nevertheless erroneous, thought indicates that this type of sliding friction is necessary to generate charge. The fallacy in this assumption is demonstrated by the operation of a Van de Graaff generator.

Van de Graaff generators purchased as laboratory equipment can easily produce 100,000 volts on a metal sphere. The source of charge in this device is contact of a rubber belt by a cloth-covered pulley. There is little or no sliding motion between the belt and pulley yet we are able to produce large quantities of charge and high potentials. There is a limit, however, to the amount of charge produced by a single contact even in the Van de Graaff generator.

The limit on charge produced is caused by electrical breakdown of the air between the contacting surface after the surfaces are separated slightly. When sufficient charge builds up, the air becomes conducive and current flows between the surfaces. An estimate of the maximum charge density which can be held by a plane surface in air is 2.65×10^{-9} coulombcm^2. In the Van de Graaff generator, charge densities as high as one fourth this limit have been observed. For the case of a single insulating sheet where two surfaces are exposed this limiting charge density is doubled.[4]

Thus far we have not considered what happens when the two charged objects are separated by large distances after charging. Before separation the two objects have equal and opposite charge at their interface; hence, the net electric field outside of the system is zero. If the objects are now separated the potential difference or voltage between them rapidly increases. This operation is similar to separating the plates of a charged capacitor thereby greatly increasing

the voltage on them. If, during separation the potential difference of the objects becomes sufficiently high to cause the air between them to conduct, an electrical spark may be formed. This spark can ignite an explosive atmosphere if there is sufficient energy available in the discharge. In general, good conductors produce energetic sparks which discharge the entire object and insulators produce low energy sparks which discharge only small areas of the surface thus leaving large accumulations of charge behind.

The object charged by contact is capable of discharging into any object of differing voltage. This discharge may cause a spark which can ignite an explosive atmosphere or pass current through the bridgewire of a sensitive electroexplosive device producing sufficient heat for ignition.

The sign of the charge produced on each object rubbed together is easily determined by experimentation. Prediction of the sign is aided by the triboelectric series shown in Figure 2. Thus, one could rub nylon and wool together and expect the nylon to receive positive charge and wool to receive negative charge. These series do not predict the magnitude of the charge produced. In the worst case the charge magnitude for each object is the limiting charge density discussed previously.

FLOW CHARGING

Charging of flowing liquids is a serious problem to handlers of aviation gasoline and other spark sensitive liquids. For flowing liquids, charge is formed locally in the liquid with equal and opposite charge residing on the boundary. This charge production is attributed to electrolytic action between metals and solutions of the proper ph, the migration of charge through a semi-permeable boundary or separation of charge during turbulent flow. There are other factors contributing to flow charging of fluids; however, the important fact is that it occurs frequently and can produce extremely high voltages between the fluid and container, or charge the reservoir or recipient container to dangerous levels.

Here we must make the distinction between liquid flow charging and charging due to an air stream which may contain dusts. Dusts are occasionally ignited by electrostatically produced sparks in blower systems. The origin of the charge is a combination of contacts between the dust and the walls of the air duct or other dust particles or air molecules. Pouring of sensitive powders becomes hazardous for similar reasons. There is clearly little or no electrolytic or other fluid charging phenomena involved, however the air or powder is usually considered as a flowing fluid.

INDUCTION

Ambient electric fields can induce charges on otherwise uncharged objects. If a conducting object is placed in an electric field it will experience charge migration. For metallic objects the electrons are mobile and will be attracted or repelled to the limits imposed by the surface of the object. The relocation of these electrons causes a distribution of positive charge to appear diametrically opposite the negative charge. If the object is now grounded an electron current will flow until all the positive charges are neutralized. Thus we have added a net charge to the object. If the ground is now removed and the ambient field changed, the net charge is available to other objects which it may contact. The resulting electrical discharge, if sufficiently energetic, can ignite explosives.

The ambient field can be the earth's electric field, which may reach 5,000 volts per meter prior to a thunderstorm or the field of a charged object such as a recently removed jacket hanging on a coat rack. The object in each case could be a person, and the person charged by induction could initiate an explosion.

ASYMMETRIC FRICTION

Charge may be generated by rubbing one object upon another although the objects are composed of the same material. The present explanation is that heating of the rubbed object allows charge carriers to diffuse

causing those with high coefficients of diffusion to be in excess on the hot surface. For example, two pieces of ice may be charged by rubbing one across the other. This action aids in explaining charge buildup in thunderstorms and in the charging of fibers drawn across similar fibers at the high speeds used in textile looms.

ELECTROSTATIC CHARGE MITIGATION

Now that common methods of charge generation have been discussed let us look at practical methods for reducing net charge and charge production rates.

The first method involves short circuiting and grounding of all charge generators on the objects involved. This implies that the surfaces of the objects be coated with some substance which reduces the surface resistivity sufficiently to prevent a net charge from accumulating. In practice this coating may actually influence the charge generators and reduce or increase their charge productivity; however, the charge will now be distributed over the entire object and can be drained off easily by grounding.

The resistivity desired for the conducting film depends on the rate at which charge is generated. Since the charge production rate depends on many factors such as the relative speed of the two objects undergoing frictional charging, we must experimentally determine the effectiveness of such a treatment. An experiment of this type would necessarily be performed under the exact conditions present in the area of concern. As an example consider a hotel rug which has been known to charge guests walking across it. In the laboratory two samples of the rug would be used, one for control and the other to be treated with various antistatic solutions. The humidity and temperature at the hotel must be simulated and experiments with every possible shoe type

and style of walk must be tried. The type of floor upon which the rug lies usually determines the person's capacitance, hence it also must be simulated. An old doorknob could be used for a discharge point and a qualitative measurement would consist of judging the treatment as successful when no shock sensation is felt. In the case of explosive atmospheres more precise measurements must be made.

It is wise to remember that charge production rates depend on a number of circumstances but charge reduction rates depend only on resistivity. When the rate of reduction is made equal to the rate of production the object cannot be charged further.

The antistatic solutions containing quaternary ammonium salts or similar hygroscopic agents use their attraction of water moisture to produce a conducting film on a treated object. This type of mitigation works well with plastic foams and other packaging materials; however, it is easily removed from clothing by laundering. For clothing a more permanent type of treatment is necessary. This treatment ranges from adding conductive fibers in the textile weave to forming permanent coatings of conductive film over the textile.

The second method of electrostatic mitigation prevents charge production by changing the surface characteristics of the objects involved. In general some charge will always be produced due to asymmetric friction or other means; however, by using a coating which has less propensity for contact charging, the net charge available may be reduced to

safe levels. This coating can be some type of paint for packaging materials or a fabric finish for clothing. Since the coating may produce charge by contacting a specific object, the test for effectiveness of this treatment would certainly involve a determination of contact charge available from all objects which the treated material could contact. Also any detrimental effects from abrasion or laundering should be determined and considered in application of the treatment.

A particularly subtle but serious problem encountered with use of particular antistatic treatments is the treatment's inability to withstand storage for long periods of time. Apparently some of the treatments react with the treated material to form a surface which has a high electrostatic propensity. The work of Ward[6] in this area is illustrated in Figures 3 and 4. The arbitrary units of voltage represent electrostatic propensity and the storage time is in weeks duration.

A third method of mitigation is to simply raise the relative humidity until charge production is reduced. This process coats the charge generating objects with a film of moisture which, due to the impurities present, conducts electrical current. Thus all objects in a room of high relative humidity are at approximately ground potential at all times. The air in areas of high relative humidity is actually a better insulator than dry air and it must be realized that direct contact of objects in such an environment is the only method of grounding.

EXAMPLES

Last year our personnel received a metal storage drum containing polyurethane foam dunnage. We were to investigate an electric spark which was reported to occur upon removal of the stored device from the dunnage. Treatment of the dunnage with an antistatic solution solved the problem and the appropriate recommendations were made.

Later our ammunition handlers were being shocked when they removed a rocket seat pack from its plastic foam container. In this case the outer container was a wooden box and the foam container was enclosed by a polyethylene bag. Two ordnancemen were required to slide the tight fitting bag from the foam container. When the foam container was opened exposing the rocket pack, we measured over 15,000 volts between the rocket pack and the man opening it.

Of the several treatments on hand we first tried the one proven successful by the dunnage tests. The foam was coated as before and the handling procedure was re-enacted. Again we measured more than 15,000 volts.

A little thought revealed that the treatment must reduce charge production and not serve as a short circuiting agent. To prove this we charged the rocket pack in its foam container. Then we noted the length of time required for discharge of the pack through the foam to a grounded table top. The same test was performed on the treated

container, the results being nearly identical. We then applied a treatment containing quaternary ammonium salts to another container. The discharge time became too short to measure with our instruments. Further testing by executing the handling procedure showed this treatment would solve the shock problem. The treatment was not recommended in this case, however, since the hygroscopic quaternary ammonium salts may cause corrosion of metals or other detrimental effects.

The problem was finally solved by building the electrostatic grounding probe. This probe is useful for safely grounding electrostatically charged ammunition or other charged objects in spark sensitive atmospheres. In principle the probe permits a low energy spark to occur in the atmosphere. Any further sparking occurs in a closed chamber containing an inert gas. The probe is shown in Figure 5. The resistors are 22 megohm each and provide current limiting to prevent a high power spark. Also accidental contact with an electrical power line does not produce a hazard. The probe operates satisfactorily at voltages up to 35KV.

Another example of the electrostatic problems under investigation at the Naval Weapons Laboratory is the electrostatic charge accumulated on helicopters and the effect of this charge on externally carried ordnance. This problem develops from a program to utilize helicopters in delivering supplies of ordnance between ships at sea.

Helicopters in flight produce electrostatic voltages of 20,000 to 100,000 volts or more by accumulating electrical charges. The problem of reducing this accumulated charge is unique in that conventional mitigation techniques cannot be applied. There is no way to continuously ground a flying helicopter, nor can the rate of charge production be reduced sufficiently by coatings or paints.

Searching for a method of neutralizing charge accumulated by a helicopter, the Army, and later private industry, has developed an active electrostatic discharger. This discharger system mounts on the aircraft and produces a controlled ionic discharge to the surrounding air. A field sensor is used to detect the charge on the airframe and to control two high-voltage power supplies. Ions are expelled from the airframe as fast as they accumulate thus keeping the aircraft uncharged. Tests indicate that the system can reduce the electrostatic voltage on a helicopter by 80% or more. But, this is not sufficient since the system cannot reduce the voltage induced by the earth's electrical field which can reach values as high as 5,000 volts per meter. Additional sensor development may correct this deficiency.

Until a reliable discharger becomes a reality another method of neutralizing the charge must be used. In this case an old, well-known technique for protecting objects from electrostatic charges and fields called a Faraday shield, has been employed. The Faraday shield is simply a conductive surface which surrounds an object preventing free

electrical charges or fields from contacting it. The Faraday shield technique is very useful in protecting ordnance or explosive items from electrostatic energy where the items are only temporarily exposed to the energy and can be totally surrounded by a conductive surface during the exposure. Logistic areas are most often suited to the Faraday shield protection method.

EVALUATING THE ELECTROSTATIC HAZARD TO EXPLOSIVES

SENSITIVITY OF EXPLOSIVES

In order to determine the probability that a particular charged object can ignite an explosive or electroexplosive device a reliable measurement of explosive sensitivity must be made. It is desirable to perform the sensitivity measurements with some degree of safety; hence, one usually places the explosive in a special chamber capable of containing the blast and fragments produced. Actual testing is achieved by designing a simulator circuit which produces an accurate reproduction of the electrostatic discharge at the explosive.

The energy threshold of the explosive for this particular hazard may be determined by a statistical analysis of the results of several tests with this apparatus. Statistics useful in determining energy thresholds are the normal distribution using the firing energy and the number of devices fired at that energy as data. It should be clear that the results of this test do not apply to all situations even with the same explosive. For instance, the human being may present an electrostatic hazard to an electroexplosive device. Present standards for evaluating the electroexplosive device would involve using a capacitor, resistor, and electroexplosive device in a series circuit for simulation. But does the circuit reproduce the actual discharge of the charged human? In general the answer is no. Variations in the circuit inductance can cause drastic changes in current, power, and pulse shape thus yielding an unreliable result.

The best method for constructing a simulator circuit for the human is to look at the actual current pulse formed by discharging a charged person into an inert or dummy explosive device. This is done by means of a high speed oscilloscope and camera. From this photograph values of resistance and inductance may be found. Capacitance is largely dependent on the shoe worn and may be measured with an impedance bridge. A human charged sufficiently to ignite an electroexplosive device will usually produce a spark in the air at the point of contact. Such a spark is simulated by an extremely fast switch with negligible resistance while closed. A spark gap is probably the easiest and most accurate method for simulating this switching action. Triggering of the spark gap without adding energy to the simulator circuit may be achieved by using either a laser beam focused between the electrodes or by reducing the gas pressure within the gap. When the simulator is constructed it is usually necessary to look at the pulse produced and compare this to that of the actual discharge. At this time small adjustments of the circuit may be necessary to achieve an accurate pulse reproduction.

ENERGY AVAILABLE FROM CHARGED INSULATORS

For a charged conductor, such as a human, we find that the energy available in a discharge is equal to one half the product of the measured capacitance and the square of the measured voltage. Insulators, however do not discharge all their charge in a single discharge. In

fact, almost an infinite number of discharges are necessary to completely discharge a good insulator. Thus a value of capacitance cannot be assigned to an insulator, and the energy available in a single discharge is unknown.

Due to the limiting charge density there is, however, a maximum energy available in a single discharge. Construction of a simulator for insulators to obtain explosive sensitivity may be difficult due to problems encountered in displaying the pulse produced. Also there may be a wide range of pulse types from a single insulator, thus making simulation impossible.

To circumvent these problems we can only measure the maximum energy available and compare this value to the lowest threshold found for the particular explosive involved. If there is nearly the amount of energy necessary for ignition, the insulator should be antistatically treated to prevent charge accumulation. Measurement of this energy may be achieved by calorimetric methods or more sophisticated current squaring methods. The calorimetric method involves passing the discharge current pulse through a resistor and noting the temperature rise. From this data and a knowledge of the configuration of the resistor the energy may be calculated. The current squaring method uses a resistor and a solid state multiplier to produce an analog of I^2R which is the power dissipated in the resistor. The output is then integrated to give the energy available.

Both of these methods are being tested in our laboratory and development of a hand held device which will quickly indicate the energy available from any charged object is planned. With this device on-the-spot measurements of energies will be possible. These will greatly aid the evaluation and determination of an electrostatic hazard.

USEFUL REFERENCES

(a) Arthur, D. F., "A Review of Static Electrification", The Journal of the Textile Institute, December 1955, Vol. 46, #12, p. T721

(b) Ballou, J. W., "Static Electricity in Textiles", Textile Research Journal, February 1954, p. 146

(c) Barnard, Kenneth H., "Static Electricity in Textiles", American Dyestuff Reporter, February 14, 1955, p. P111

(d) Buschman, E. H., "Recent Developments in Flooring for Hazardous Areas", Naval Ordnance Station, Indianhead, Maryland

(e) Elliot, Robert S., Electromagnetics, McGraw-Hill, New York, 1966

(f) Evershed, S., "The Characteristics of Insulation Resistance", Journal of the Institute of Electrical Engineers, Vol. 52:51, 1914, p. 51

(g) Keller and Hoelscher, "Development of Static Charges in a Non-conducting System", Industrial and Engineering Chemistry, Vol. 49, #9

(h) Klinkenberg, A., "Laboratory and Plant-Scale Experiments on the Generation and Prevention of Static Electricity", Division of Refining, Vol. 37, #III, 1957, p. 65

(i) Lehmicke, D. J., "Static in Textile Processing", The American Dyestuff Reporter, November 28, 1949, p. P853

(j) Loeb, Leonard B., Static Electrification, Springer-Verlag, Berlin, Germany, 1958

(k) Ramer and Richards, "Correlation of Electrical Resistivities of Fabrics with Their Ability to Develop and to Hold Electrostatic Charges", Textile Research Journal, Vol. 38, #1, January 1968, p. 28

(l) Silsbee, Francis B., "Static Electricity", NBS Circular C438, U. S. Government Printing Office, 1942

(m) Vitkovitch, D., Field Analysis, Experimental and Computational Methods, D. Van Nostrand Co. Ltd., London, New York, 1966

REFERENCES CITED

(1) Ballou, J. W., "Static Electricity in Textiles", The Textile Research Journal, 1953

(2) Henry, P. S. H., "Survey of Generation and Dissipation of Static Electricity", British Journal of Physics, 1955

(3) Lehmicke, D. J. "Static in Textile Processing", The American Dyestuff Reporter, 1949, p. 853

(4) Loeb, Leonard B., Static Electrification, Springer-Verlag, Berlin, Germany, 1958

(5) Silsbee, F. B., NBS Circular C438, 1942, p. 39

(6) Ward, G. R., "Antistatic Action Versus Molecular Structure", American Dyestuff Reporter, 44:220, 1955

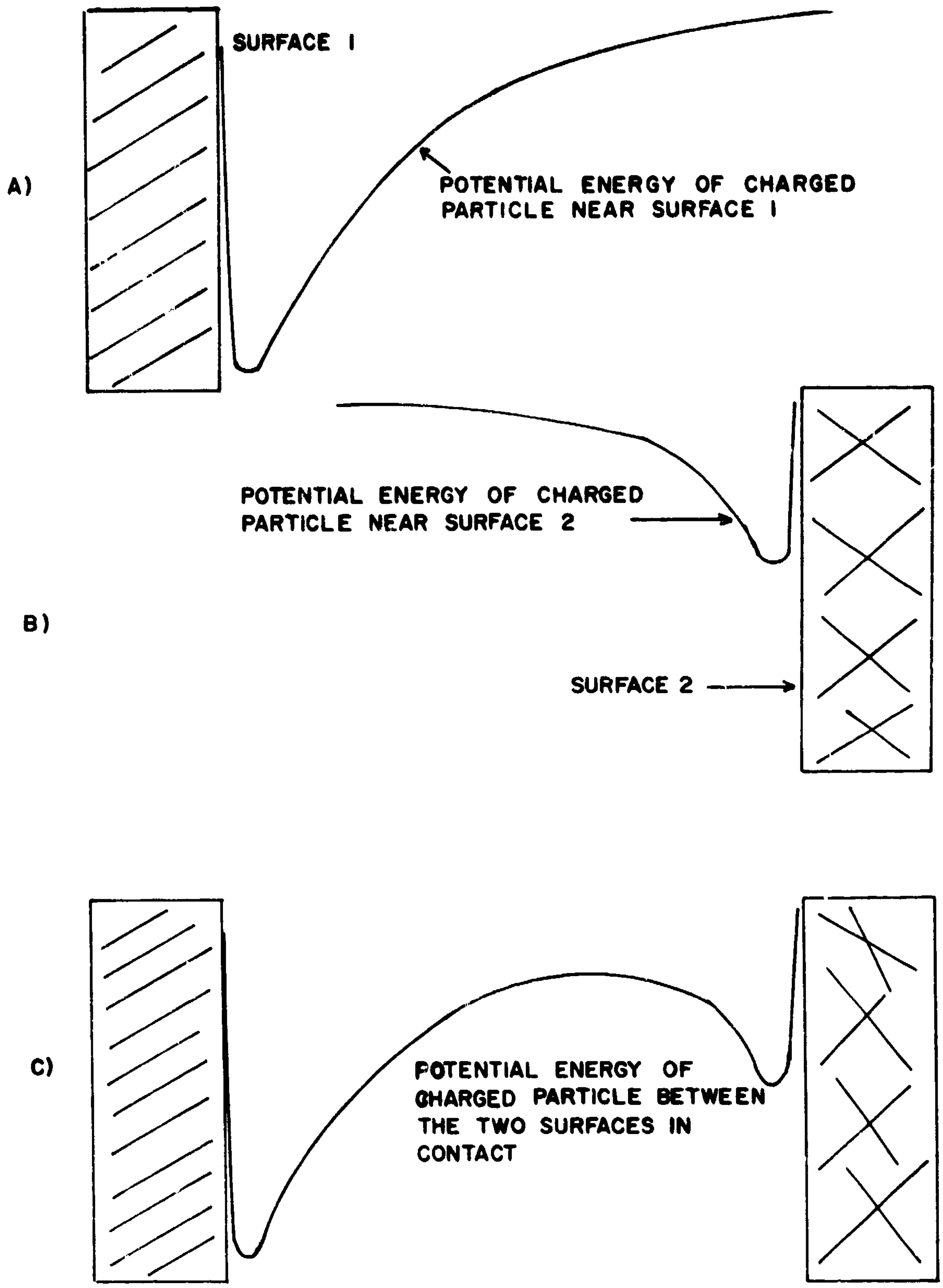


FIGURE I. VOLTAGE PROFILES OF: A) ONE OBJECT B) A SECOND OBJECT DIFFERING FROM THE FIRST, C) BOTH OBJECTS IN CONTACT

1. **Tribo-Electric Series for Various Materials**

+

Asbestos
Glass
Mica
Wool
Cat's Fur
Lead
Silk
Aluminum
Paper
Cotton
Woods, Iron
Sealing Wax
Ebonite
Ni, Cu, Ag, Brass
Sulfur
Pt, Hg
India Rubber

-

(Source) NBS Circular C438, by Francis B. Silsbee, 1942, p. 39

2. **Tribo-Electric Series for Various Materials**

+

Glass
Human Hair
Nylon Yarn
Nylon Ploymer
Wool
Silk
Viscose Rayon
Cotton
Paper
Ramie
Steel
Hard Rubber
Acetate Rayon
Synthetic Rubber
"Orlon" (trade name by du Pont)
Saran
Polythene

-

(Source) From "The American Dyestuff Reporter", Article by D. J. Lehmicke entitled "Static in Textile Processing", 1949, p. 853

3. **Tribo-Electric Series for Textiles**

+

Wool
Nylon
Silk
Viscose Rayon
"Cordura"* (High Tenacity Rayon) (Human skin in this region)
Cotton
"Fiberglass"**
Spun Ramie } Chrome plated
Acetate } Metallic surface
"Dacron"* (Polyester yarn)
"Orlon"* (Acrylic yarn)
Polyethylene
Saran

-

RH = 15%
** Owens Corning trademark
* Du Pont trademark
Adapted from "The Textile Research Journal", article by J. W. Ballou entitled "Static Electricity in Textiles"

FIGURE 2. TRIBOELECTRIC SERIES

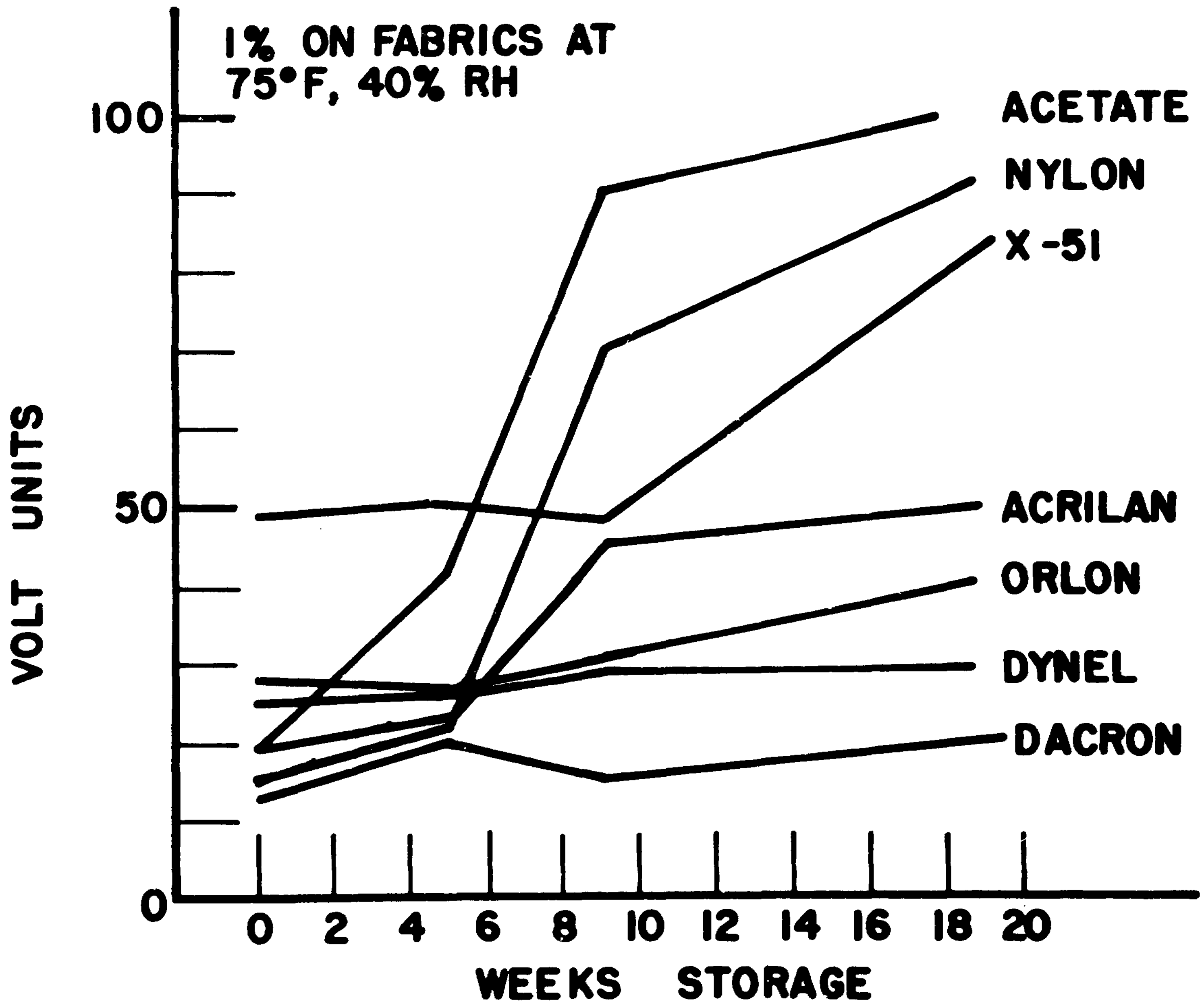


FIGURE 3. ANTISTATIC TREATMENT DETERIORATION FOR 10-MOLE OXYETHYLATED NONYLPHENOL

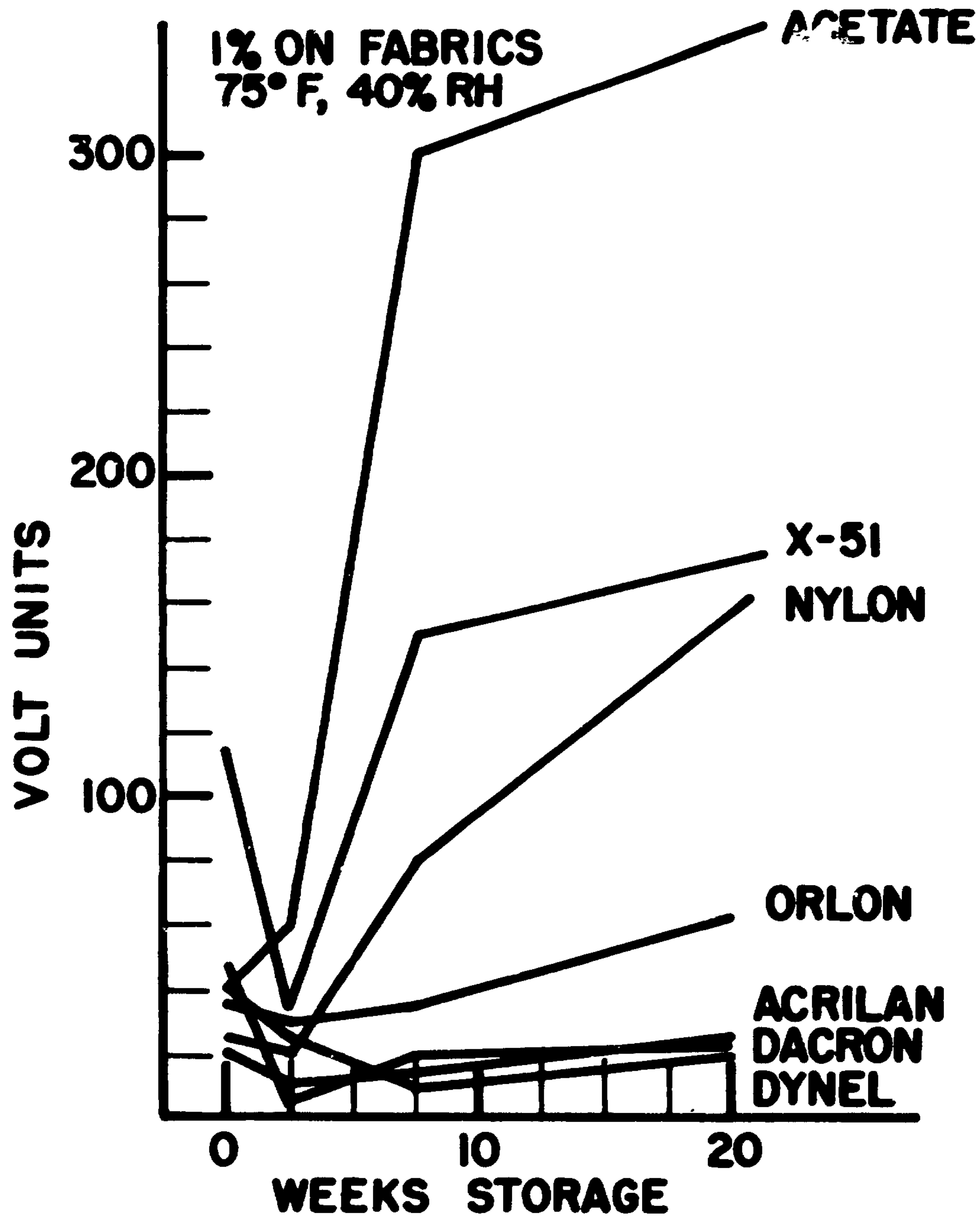


FIGURE 4. ANTISTATIC TREATMENT DETERIORATION FOR 10-MOLE OXYETHYLATED DODECYL MERCAPTAN

ELECTROSTATIC GROUNDING PROBE

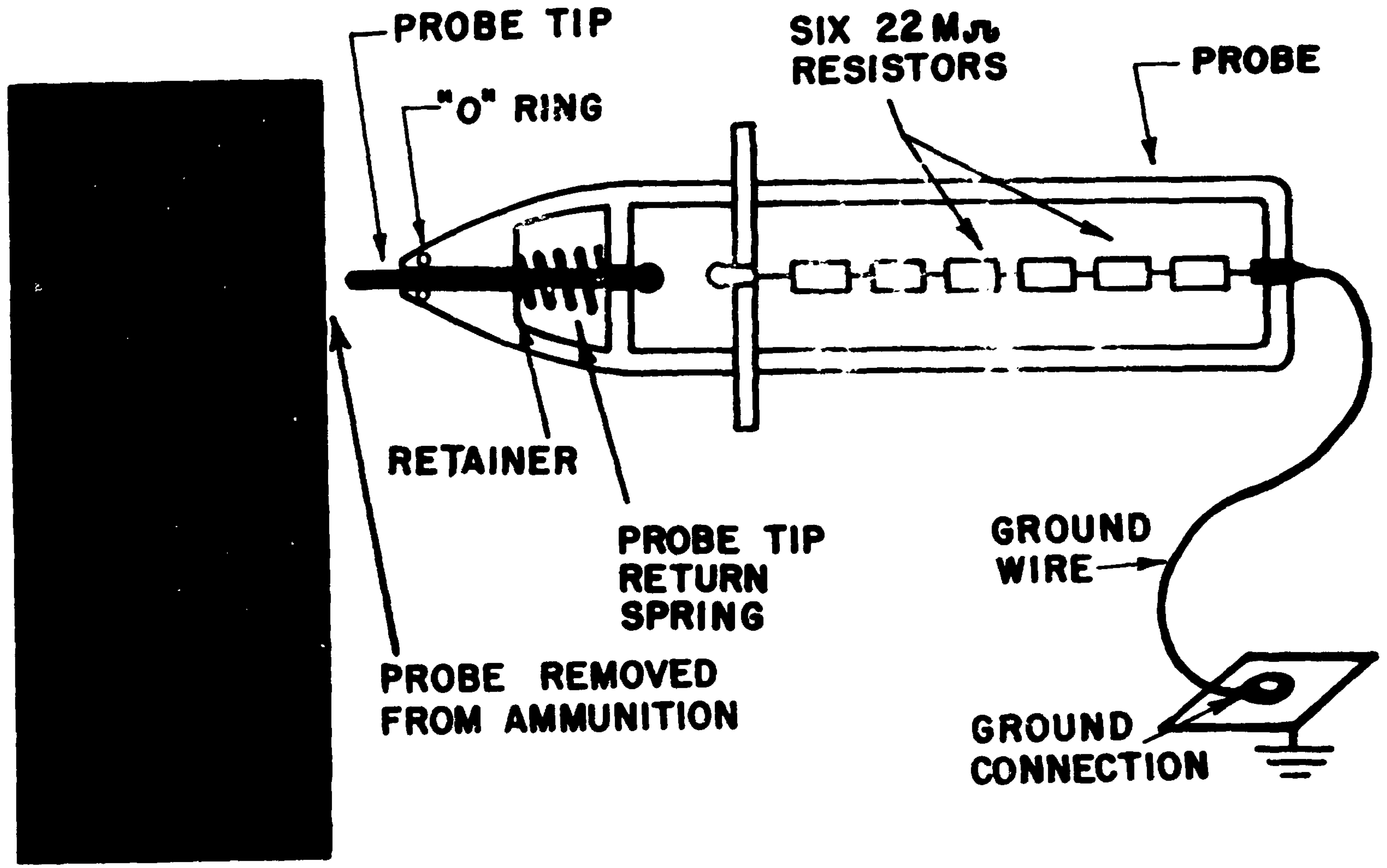


FIGURE 5.

BLANK PAGE

THE CURRENT NASA SAFETY PICTURE

by

Erskine E. Harton, Jr.
National Aeronautics & Space Administration
Washington, D.C.

Mr. Chairman, Members of the Board and Staff, distinguished guests and colleagues, thank you for the honor and real privilege of talking with you for the next few minutes--for the opportunity to present the NASA Safety picture. Mr. Bob Helgeson, the NASA Director of Safety conveys his regards and expresses his wholehearted support for the meeting.

The ASESB holds a special meaning for me because, as a brand new neophyte, I cut my safety teeth so-to-speak as a member of "Bob Herman's" Minimum Test Criteria Work Group.

We have witnessed many changes in NASA safety-wise during the past year, as a result of the Apollo-204 accident. There has been keen interest, as well as obvious misunderstanding, expressed by many outsiders on just what has transpired.

Before dealing with NASA activities directly related to the seminar theme, may I digress long enough to point out the basic features of the new NASA Safety Program--the organization, policy, objectives, status and plans? In my opinion effective communication is a key element in a successful safety program and good safety interfacing within and outside the Federal Government results in large degree from a clear understanding of just how the other safety organizations are constituted and function.

NASA's overall safety policy is a commitment of the entire NASA organization to effectively apply the most up-to-date safety technology to every aspect of in-house and contractor activities. This breaks down more specifically into the six elements shown in Figure 1. This policy is described in more concrete terms a little later as we look at the organizational and functional aspects of the NASA Safety Program.

History teaches us lessons, but the emphasis must be on finding the troubles before they find us. The real safety breakthrough is going to come from our being able to recognize hazards, particularly in the concept and design stages, and then designing to eliminate or effectively control them.

The five basic objectives, as shown in Figure 2, reflect a dynamic approach to safety management with total involvement.

NASA SAFETY PROGRAM POLICY

- TO EMPHASIZE IDENTIFICATION OF HAZARDS, COMMUNICATION OF SAME.
- TO DEVELOP PLANS AND CONDUCT ACTIVITIES FOR HAZARDS ELIMINATION, CONTROL OR APPROPRIATE ASSUMPTION OF RISKS.
- TO GIVE ADEQUATE EMPHASIS TO SYSTEMS, INDUSTRIAL, PUBLIC, MANNED SPACE FLIGHT AND AVIATION AREAS OF SAFETY AND TO SAFETY SERVICES.
- TO PROPERLY AND PROMPTLY INVESTIGATE ACCIDENTS AND TAKE PROMPT AND EFFECTIVE FOLLOW-UP ACTIONS.
- TO EMPHASIZE COORDINATION WITH OUTSIDE AGENCIES AND GROUPS ON MATTERS OF SAFETY.
- TO HAVE ADEQUATE EMERGENCY PLANNING AND CONTROL.

FIGURE 1

OVERALL NASA SAFETY PROGRAM OBJECTIVES

- o AVOID LOSS OF LIFE, INJURY OF PERSONNEL AND PROPERTY LOSS TO THE MAXIMUM PRACTICAL EXTENT.
- o HAVE AN ACTION ORIENTED PROGRAM, AS OPPOSED TO REACTION.
- o TAKE AN ACTIVE AND LEADING ROLE IN MATTERS OF SAFETY, WITH PARTICULAR EMPHASIS ON SYSTEMS SAFETY.
- o WORK UNDER A NASA-WIDE FAMILY CONCEPT OF COMMUNICATIONS AND KNOWLEDGE.
- o SEEK A CLEAR UNDERSTANDING OF SAFETY RESPONSIBILITIES AND INVOLVEMENT FROM TOP TO BOTTOM.

FIGURE 2

Each one of the specific objectives summarized in Figure 3 is worthy of detailed comment, but let it suffice to say they are all being pursued vigorously. As a noteworthy example, the NASA Director of Safety position has been raised from the GS-15 to the GS-18 level. This certainly equates the grade to the responsibility; and I sincerely hope that this initiates a long-overdue chain reaction to improve the status of professional safety personnel everywhere.

Without clear definition of responsibility and requirements, it is impossible to effectively carry out any mission. NASA's approach is outlined in Figure 4. Basically, safety functional (staff) management sets the policy and requirements and oversees the safety program which is implemented by the line organization.

Safety management has real teeth by virtue of the NASA Director of Safety's authority to stop any operation under emergency conditions. I believe that this will never come to a test, because I am unable to envision any program manager purposely wanting to jeopardize his program on a safety question.

Figure 5 shows the overall NASA organization. The four offices at the bottom are the Institutional Offices by whom the field installations are directed and in which the technical program managers reside. The NASA Director of Safety reports to the Associate Administration for Organization and Management.

Figure 6 also indicates the NASA Safety Office location and permits me to point out how the NASA Safety Office has been elevated organizationally--previously, it came under the Office of Administration.

The NASA Safety Office organization and its relationship to other key NASA elements are revealed in Figure 7. The circles are not indicative of personnel going around in circles or off on tangents, but are intended to illustrate that the safety functional management responsibility is centered in the NASA Director of Safety and radiates from him and through his safety management specialists--Manned Space Flight; Industrial and Public; Fire Prevention and Protection; Systems; Aviation; Hazards Identification and Safety Research; and Documentation and Data--who are responsible for developing and managing programs in those areas and, simultaneously, fully supporting each other.

The Functional Managers for Hazards Identification and Safety Research and for Documentation and Data are Executive Secretaries of the NASA Hazards Identification Committee (NHIC) and NASA Safety Standards Committee (NSSC), respectively. The former also performs liaison with the Aerospace Safety Research Programs Office of the Office of Advanced Research and Technology and with the Aerospace Safety Research and Data Institute at the NASA Lewis Research Center.

SPECIFIC NASA SAFETY PROGRAM OBJECTIVES

- o PLACEMENT OF SAFETY ORGANIZATIONAL ELEMENTS AT SUFFICIENTLY HIGH LEVELS TO ASSURE EMPHASIS AND RECOGNITION OF SAFETY RESPONSIBILITIES.
- o ESTABLISHMENT AND MAINTENANCE OF POLICIES, STANDARDS AND GUIDELINES WHICH DEFINE AN EFFECTIVE PROGRAM.
- o EFFECTIVE AND APPROPRIATE SURVEILLANCE OF CONTRACTORS.
- o IDENTIFICATION OF HAZARDS AND COMMUNICATION OF THIS INFORMATION.
- o DEVELOPMENT OF PLANS AND PROCEDURES FOR HAZARDS ELIMINATION, CONTROL OR ASSUMPTION OF RISKS.
- o PROMPT AND THOROUGH INVESTIGATION OF ACCIDENTS, INCIDENTS, MISSION FAILURES AND OTHER MISHAPS AND IMPLEMENTATION OF CORRECTIVE MEASURES.
- o CONDUCT OF REVIEWS AND SAFETY EVALUATIONS.

FIGURE 3

SPECIFIC DELEGATIONS AND REQUIREMENTS

- o LINE MANAGEMENT IS RESPONSIBLE FOR THE SAFETY OF OPERATIONS.
- o THE DIRECTOR OF SAFETY IS RESPONSIBLE FOR THE FUNCTIONAL MANAGEMENT OF SAFETY:
  - DIRECTION, COORDINATION, SUPPORT AND REVIEW
  - CLOSE WORKING RELATIONSHIPS TO BE SOUGHT
  - FREEDOM OF ACCESS OF SAFETY PERSONNEL TO ALL LEVELS
  - SYSTEM OF SAFETY DOCUMENTATION
- o THE DIRECTOR OF SAFETY HAS THE AUTHORITY TO STOP ANY OPERATION IN NASA:
  - WHERE SAFETY PROCEDURES ARE BEING VIOLATED
  - WHICH MAY COME TO HIS ATTENTION AND WHICH HE DEEMS TO REPRESENT A CLEAR, PRESENT AND UNWARRANTED DANGER
- o SAFETY PERSONNEL ARE TO PARTICIPATE IN KEY MEETINGS AND EVENTS
- o FIELD INSTALLATION DIRECTORS ARE RESPONSIBLE FOR REPORTING ACCIDENTS AND INCIDENTS AND FOR INVESTIGATIONS, UNLESS OVER-RIDDEN BY APPOINTMENT OF AN ADMINISTRATOR'S INVESTIGATION
- o NASA EMPLOYEES ARE NOT TO BE MEMBERS OF CONTRACTOR INVESTIGATION BOARDS, AND VICE VERSA. QUALIFIED CONSULTANTS AND OBSERVERS MAY BE USED FROM ANY SOURCE.
- o FACILITY OPERATIONS MANAGERS ARE TO BE DESIGNATED AND WILL BE RESPONSIBLE FOR SAFETY IN THEIR PARTICULAR FACILITIES.

FIGURE 4

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

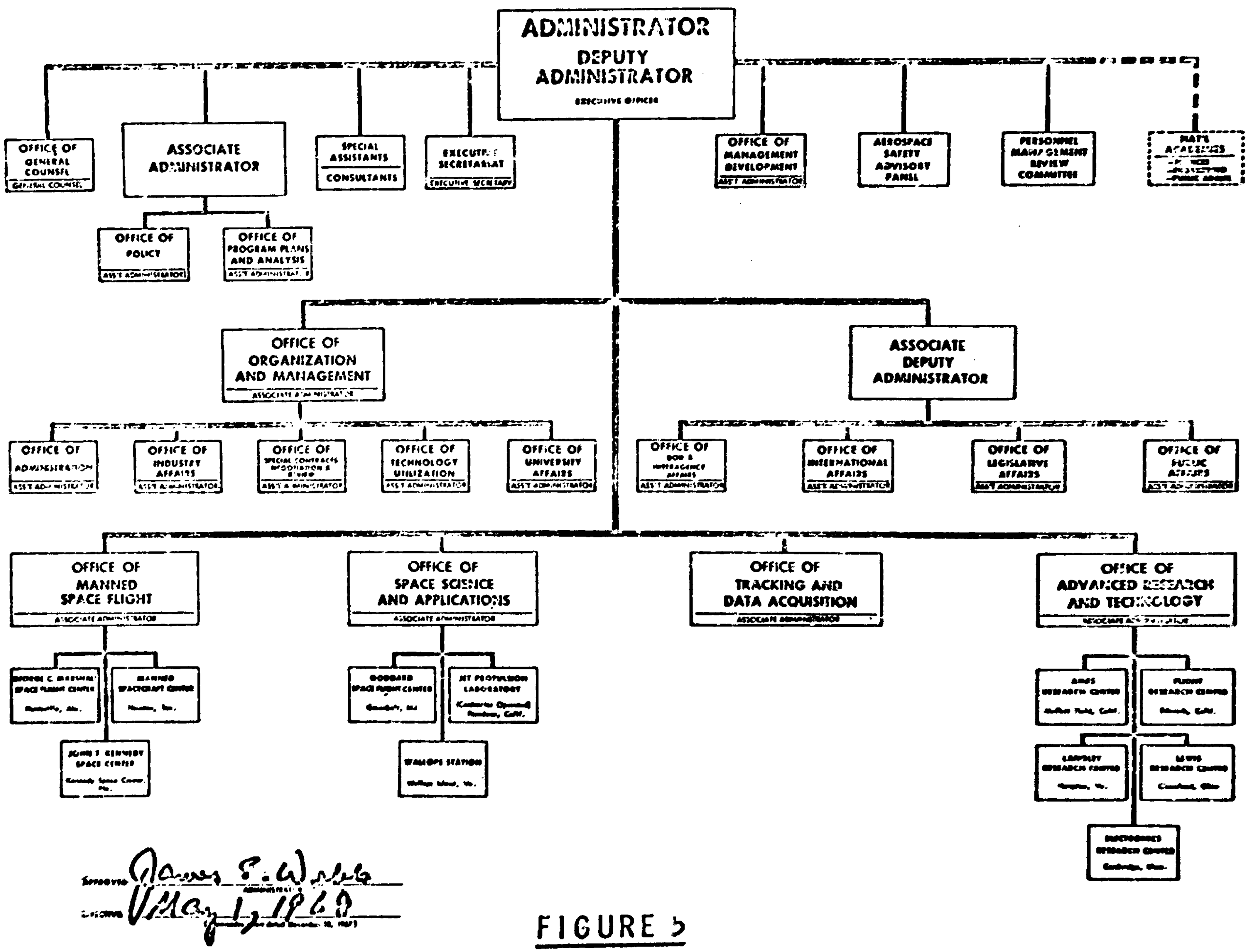


FIGURE 5

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

OFFICE OF ORGANIZATION AND MANAGEMENT

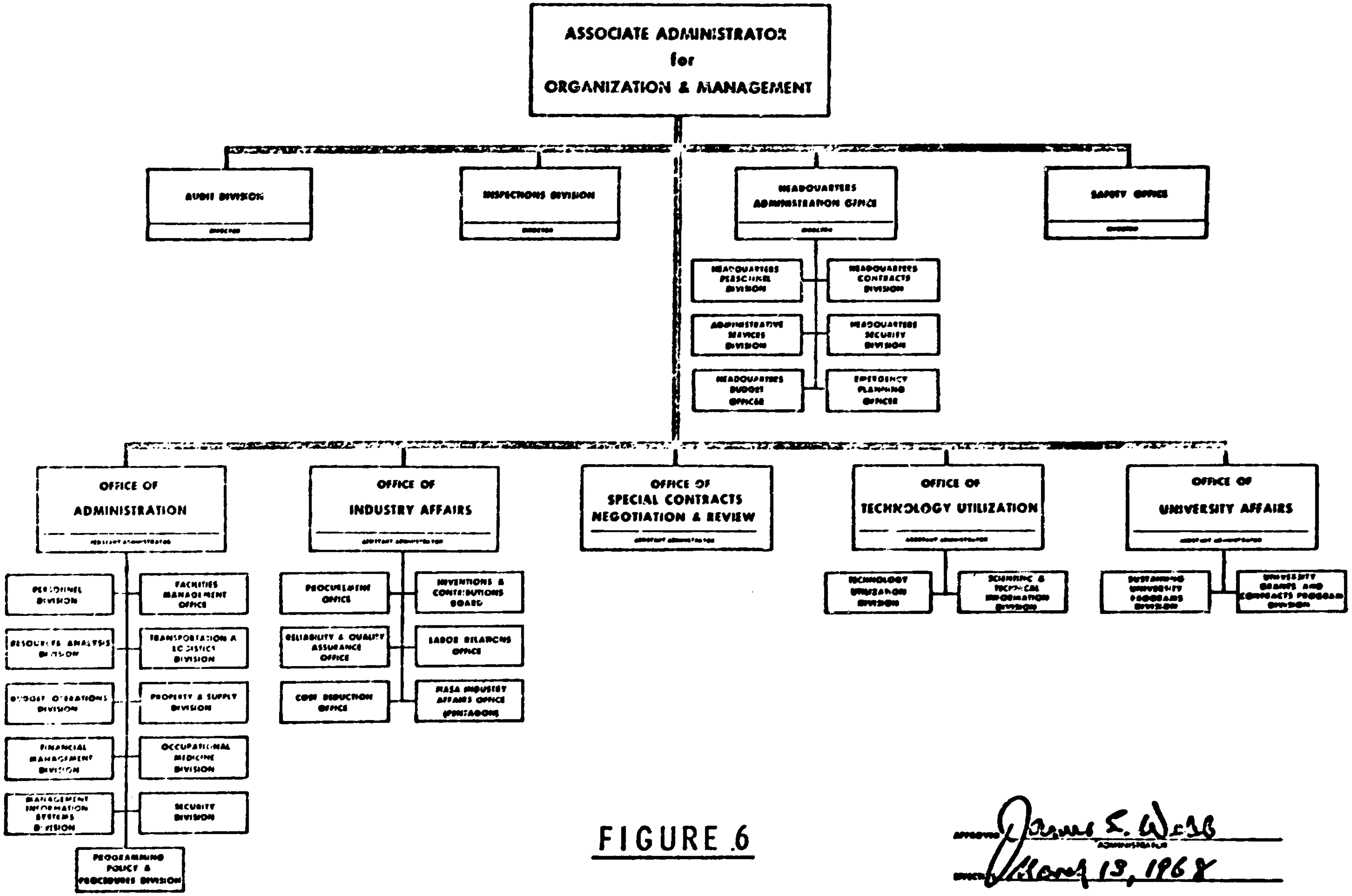
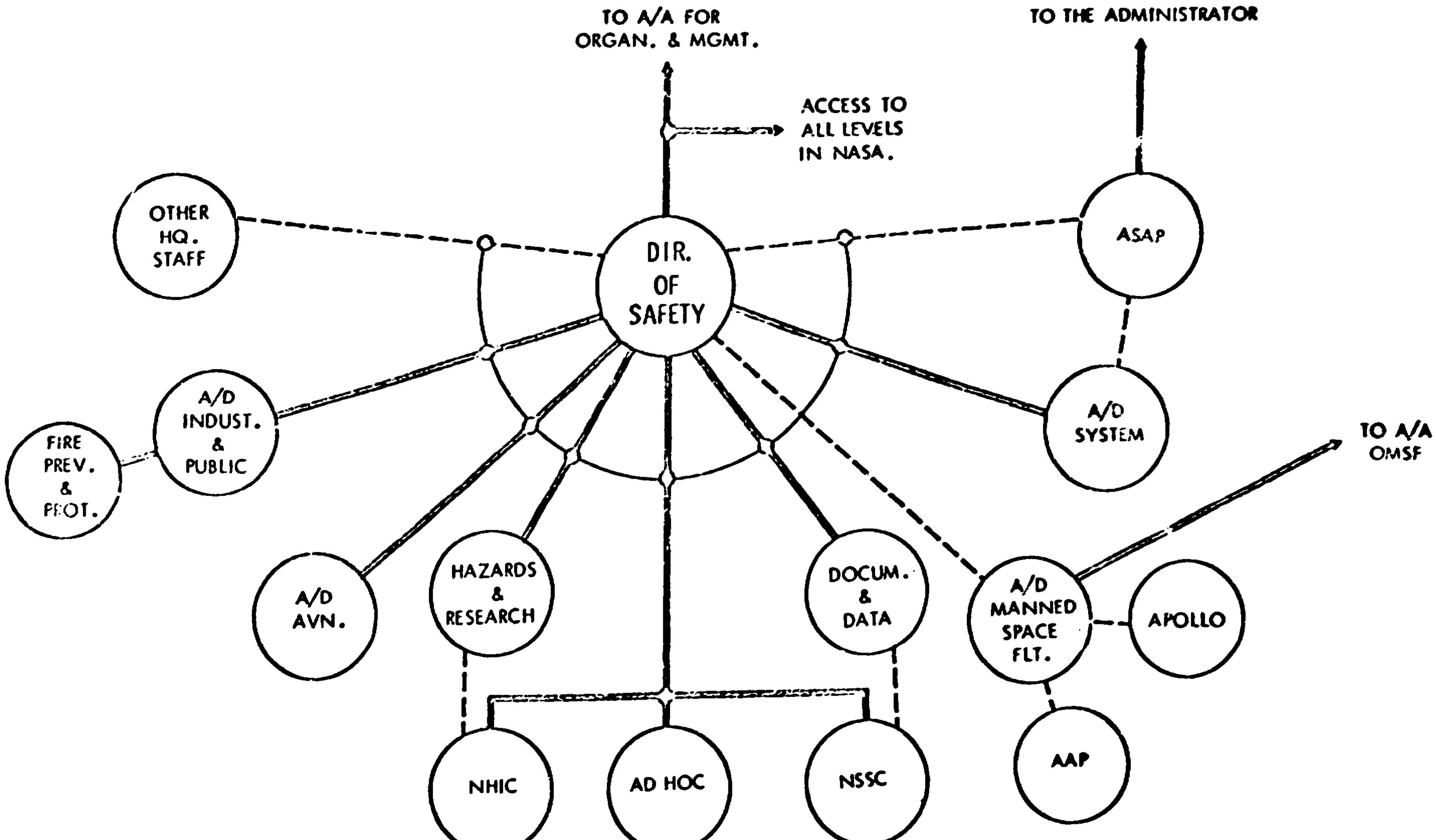


FIGURE 6

APPROVED: James E. Webb
ADMINISTRATOR
EFFECTIVE: March 13, 1968



NASA SAFETY OFFICE

FIGURE 7

NASA HQ DY69-15092
7-24-68

The Assistant Director for Systems Safety serves as Deputy to the Executive Secretary of the Aerospace Safety Advisory Panel (ASAP), which was created by Congress. Close working relationships are being developed between the ASAP and the NASA Safety Office. In the near future the two are to be physically located contiguously.

Figure 8 further illustrates the safety functional and programmatic (or line) relationships within NASA and as related to contractors.

Figure 9 introduces a relatively new term, risk management, which seems to be taking hold.

Most people would probably agree that absolute safety cannot be achieved, even though we strive to reach it and come reasonably close at times. One principal responsibility of we safety people is to point out the risks associated with hazardous situations, so those responsible for making the program/line decisions do so with full knowledge of the impact that will result if something goes wrong and of the probability of such an occurrence.

Let us turn our attention to the NHIC which consists of the nine subcommittees shown in Figure 10.

In brief the purpose, objective, and function are those appearing in Figure 11. Hazards must be identified and risks determined before they can be eliminated or controlled. While not neglecting development of the overall approach, we are giving priority to the Apollo Program. The NHIC is working on all of these aspects.

Figure 12 summarizes what the NSSC is in business to accomplish. Documentation in the form of standards and guides are a must in reaching worthwhile uniformity and coordinated action.

The place to start developing safety criteria is in the early stages of research on new materials, equipment, hardware and the like. The Office of Advanced Research and Technology (OART) has set up its Aerospace Safety Research Organization, as shown in Figure 13, to make available to all NASA and contractor elements required technical safety data; and to identify the safety-related elements of research programs--essentially all NASA's efforts are research of some kind--and to assure that essential information on hazards, not being developed as an integral part of the programs, is obtained through special studies.

The functions of the Aerospace Safety Research Programs Office are listed in Figure 14. This office oversees, from the Headquarters viewpoint the Aerospace Safety Research and Data Institute (ASRDI) is performing its function effectively and works with the latter and the NASA Safety Office in developing a coordinated approach to safety/hazards research throughout NASA.

LINE/FUNCTIONAL RELATIONSHIPS FOR SAFETY

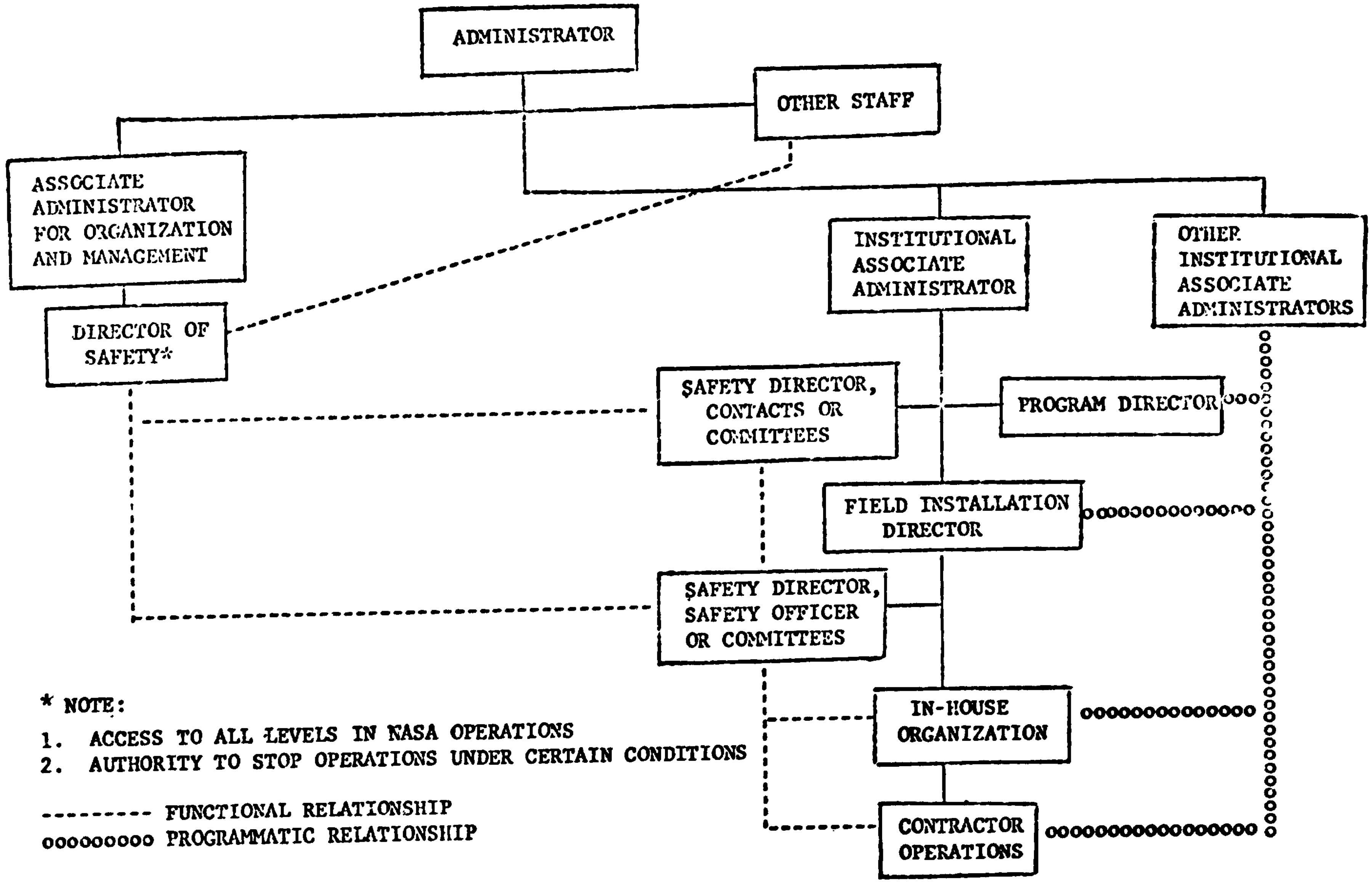


FIGURE 8

NASA Hq DY 68-16284
3-20-68

RISK MANAGEMENT MEANS

----HAZARDS MUST BE IDENTIFIED.

----HAZARDS MUST BE CONTROLLED OR MINIMIZED.

AND

----THE "RESIDUAL" RISKS MUST BE IDENTIFIED AND USED IN THE MANAGEMENT DECISION PROCESS.

FIGURE 9

SUBCOMMITTEES TO THE NASA HAZARDS IDENTIFICATION COMMITTEE

- o CREW AND MANNED MISSIONS
- o HARDWARE SYSTEMS
- o UNMANNED MISSIONS AND LAUNCH OPERATIONS
- o INDUSTRIAL AND FACILITY
- o PUBLIC SAFETY
- o TRANSPORTATION AND STORAGE
- o RESEARCH AND DEVELOPMENT
- o AVIATION
- o ENVIRONMENTAL

FIGURE 10.

NASA HAZARDS IDENTIFICATION COMMITTEE(NHIC)

FUNCTIONS

- TO DEVELOP A SYSTEMATIC PROCEDURE FOR IDENTIFICATION AND ANALYZING ALL HAZARDS AND RISKS IN NASA ACTIVITIES.
- TO DEVELOP AN INDEXING SYSTEM, CATALOGING THE IDENTIFIED HAZARDS.
- TO DEVELOP AN APPRAISAL/ANALYSIS SYSTEM TO FACILITATE A UNIFORM, THOROUGH, OBJECTIVE EVALUATION OF THE IMPORTANCE OF IDENTIFIED HAZARDS AND RISKS.
- TO EVALUATE THE APPLICABILITY OF EXISTING AND NEW ANALYTICAL TECHNIQUES(e.g., FAILURE-MODE-AND-EFFECTS, FAULT TREE AND GROSS HAZARDS ANALYSIS).
- TO ADVISE AND ASSIST THE NASA DIRECTOR OF SAFETY RE HAZARDS AND RISK IDENTIFICATION, INDEXING AND EVALUATION.

FIGURE 11

NASA SAFETY STANDARDS COMMITTEE(NSSC)

FUNCTIONS

- TO REVIEW THE SAFETY STANDARDS(e.g., CODES, GUIDES, PROCEDURES, SPECIFICATIONS AND CONSTRAINTS) THAT ARE BEING APPLIED TO NASA ACTIVITIES AND BY OTHER ORGANIZATIONS.
- TO EVALUATE SUCH STANDARDS FOR ADEQUACY AND POSSIBLE ADOPTION AS NASA-WIDE REQUIREMENTS.
- TO DETERMINE SAFETY AREAS FOR WHICH NO, OR INADEQUATE, NASA STANDARDS EXIST AND ARE NEEDED.
- TO RECOMMEND ADOPTION, AS NASA-WIDE REQUIREMENTS, APPROPRIAT EXISTING OR FUTURE STANDARDS; AND TO GENERATE OR REVISE SUCH ITEMS, IF NECESSARY.
- TO ASSIST THE NASA DIRECTOR OF SAFETY IN DEVELOPING AND COORDINATING A UNIFORM NASA SAFETY STANDARDS PROGRAM.

FIGURE 12

FIGURE 13

OART SAFETY RESEARCH ORGANIZATION

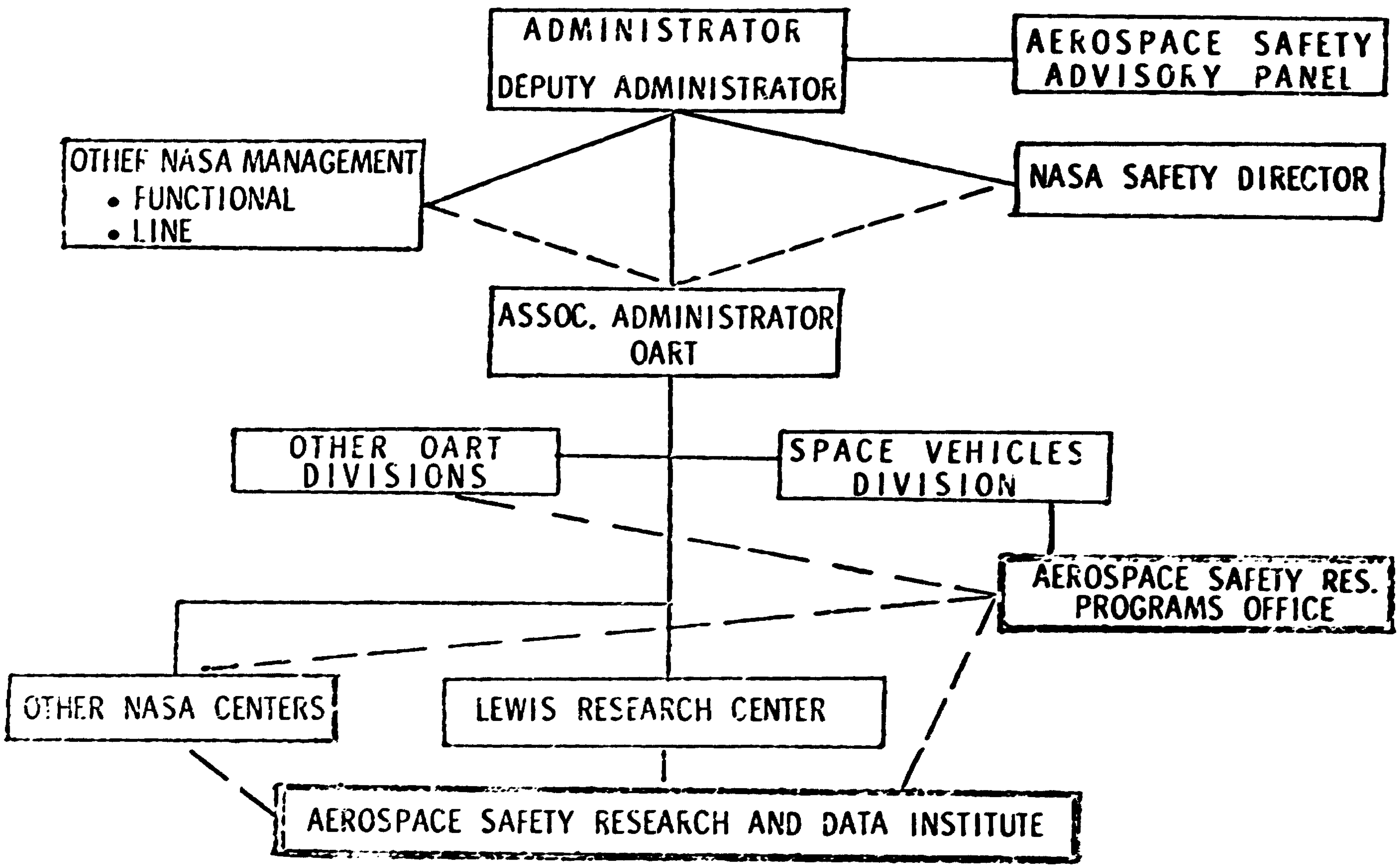


FIGURE 14

AEROSPACE SAFETY RESEARCH PROGRAMS OFFICE

FUNCTIONS

- Provide Headquarters support and collaborate with the Director of the Aerospace Safety Research and Data Institute in technical and program direction
  - Facilitate accomplishments of safety research requirements by effective utilization of NASA Centers' resources
  - Develop and present to the Associate Administrator, OART, the objectives, plans and resources required for proposed safety research
  - Maintain cognizance of new developments in aerospace technology in order to identify potential critical hazards associated with the application of this technology to aerospace activities
- Planning and management at Headquarters level of OART safety research
  - Maintain cognizance and coordinate all OART safety research activities
  - Serve as OART representative on matters relating to safety research
  - Provide support, as appropriate, to NASA Safety Director

The ASRDI, located at the NASA Lewis Research Center, under the direction of Mr. Irving Pinkel, will be providing technical safety information in a useable form to all NASA and contractor elements having a requirement, and will be funding safety/hazards research as appropriate.

Figure 15 portrays the contemplated functional operations of the ASRDI. This is an initial concept and subject to change, perhaps, before it becomes fully operational. Computerization is to play a significant, but not exclusive, role.

Let us return to the main theme, explosives safety. Perhaps some of us are going to be disappointed in not hearing a summary of safety-related research prompted by the Apollo accident. Frankly, I could not begin to cover the subject adequately in the time allotted. Instead let me reference a couple of these investigations, as I relate some activities in the explosives' realm.

The flammability laboratory at NASA's Manned Spacecraft Center has performed or contracted-out many studies on the development and evaluation of non-flammable materials as substitutes for everything from clothing to spacecraft subsystems. Much of this technology could have direct application in the explosives/propellant area. Mr. Richard S. Johnston and Dr. Matthew I. Radnofsky can be contacted for more details on these programs.

Likewise the NASA Ames Research Center published Preliminary Data From Studies of Fire Retardant Materials presented at a meeting at the Center on February 27-28, 1968. Mr. Glen Goodwin is suggested as a contact. This work relates to the development of fire protective systems. Basic chemistry of protective mechanisms was explained; preliminary material formulation and screening tests were discussed; process and material specifications were presented; and limited evaluation tests of materials in fuel fires were described.

The fire/explosive potential of hydrogen vapor mixed with air or certain other oxidizers has been recognized for some time. However, the characteristics of hydrogen have not been fully understood. The Cleveland Extension of the Space Nuclear Propulsion Office, a joint NASA-AEC organization, has continued the hydrogen safety program at the U.S. Bureau of Mines Explosives Research Center.

Other research efforts include such things as: development of a lunar/space flare gun (an emergency hand-held pyrotechnic item); and a non-electrical pyrotechnic ignition study aimed at finding a means to eliminate potential hazards from stray electrical currents. Mr. Kurt Strass, who heads up the OART Safety Research Program Office, is present and perhaps can give you more details on these and other research efforts, because he has been actively engaged in identifying the safety-related research that NASA has underway.

FUNCTIONAL CHART FOR ASRDI

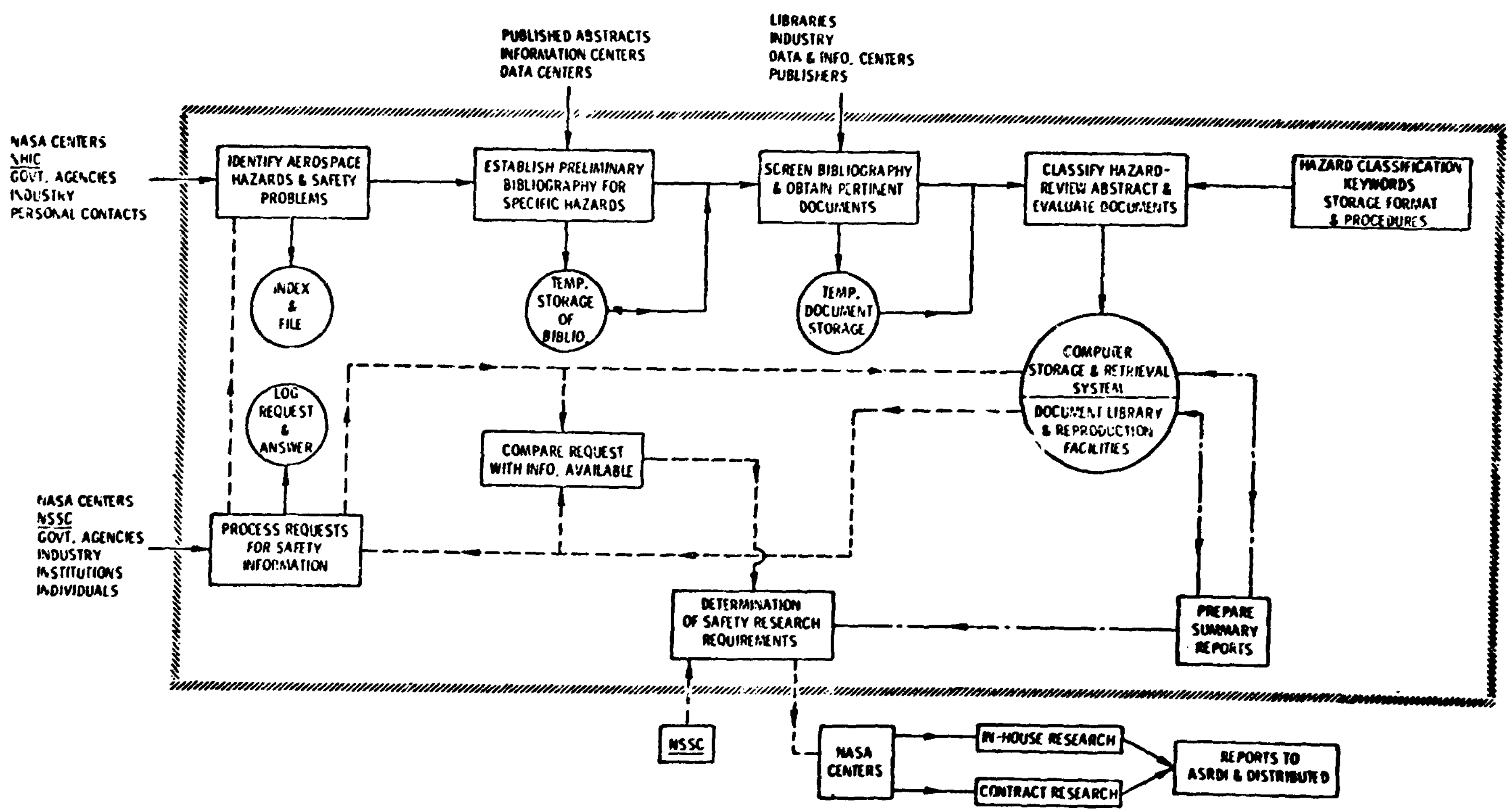


FIGURE 15

There is in the final stage of editorial review a NASA Special Publication, which is a Technological Survey on Explosives and Explosive Devices, authored by Gunther Cohn of the Franklin Institute Research Laboratories, under contract to the Technology Utilization Division, NASA Headquarters. This is aimed at the technician, administrative and others who are not professional explosives safety personnel.

The fatal barium-Freon TF accident, which occurred late last year, certainly left no doubt in anyone's mind that we must develop an effective hazardous properties' evaluation system for new chemicals and materials. We must also take another look at some of the more familiar ones, particularly as to their compatibilities and enhanced reactivity due to size reduction and/or change in purity. The ASRDI has been requested to prepare for wide dissemination a summary on the characteristics of reactive metals and halogenated hydrocarbons.

An effort is being initiated to inventory all explosives and explosive-containing devices involved in NASA activities (in-house and contractor) as a preliminary step toward coding (identification) and adopting the Minimum Test Procedures for Hazard Classification of solid propellants, solid propellant motors and devices.

Figure 16 will introduce in a vivid way my final topic, explosives identification. How such a completely contradictory and confusing color coding system could evolve is almost beyond comprehension. The vital point is that it must be corrected. The first step in our plan is to have all manned spaceflight centers and contractor-operated facilities under their cognizance inventory all ordnance items on hand and identify them by color and adjectival coding; initiate orders or directives to assure that the "in transit" and "on order" items receive the same treatment; and to promulgate a program to unequivocably assure identification of "live" and "inert" items. "Live" items are to be marked red and a permanent adjectival description is to be appropriately applied (e.g., paint, tape, metal tag). As soon as the item becomes "inert," black 45 degree diagonal lines are to be marked on the red surface and the adjectival description is to be replaced with the "inert" identification. Permanently "inert" items (e.g., those used for display, instruction and the like) are to be drilled through from two sides. Any improperly marked item is to be considered "live." This approach is then to be expanded to encompass all the other NASA installations and facilities. This is admittedly a unilateral action and can only be justified as an interim measure. Therefore, I propose that the ASESB activate a Work Group or Groups to study this problem of propellants/explosives identification and come up with a uniform, effective and simple set of criteria at the earliest practicable opportunity. We in NASA stand ready to participate in such an undertaking.

Thank you for your interest. I hope that I have provided something of value.

ORDNANCE COLOR CODES					
CONTR. PROJ.	INERT		LIVE		COMMENTS
ATLAS AGENA [illegible]	GREEN		RED		ATLAS
ATLAS AGENA SC	BLUE		RED		AGENA
[illegible]OR AGENA [illegible]LAS	NONE		SUPPLIER COLOR (NONE)		THOR
[illegible] AGENA [illegible]	BLUE		SUPPLIER COLOR (NONE)		AGENA
ATLAS CENTAUR [illegible]	GREEN		RED		ATLAS
ATLAS CENTAUR	GREEN		RED		CENTAUR
[illegible] CHRYSLER	BRIGHT ORANGE		NONE		
[illegible]	RED		NONE		
[illegible]	GREEN		RED		
[illegible]	RED		GREEN		
BOEING [illegible]	BLUE WHITE LETTERING	INERT	YELLOW		COLORS IN FED. SPEC. 595
BENDIX [illegible] MAGAZINE AREA	WHITE W BLUE LETTERING	INERT	NONE		
MCDONNELL	RED & WHITE CANDY STRIPE		RED		
POLARIS LMSC	YELLOW W BLACK STRIPE		RED		
HERCULES POWDER	NONE HOLES IN CASE		RED		
A.P.G. MARYLAND	BLUE		YELLOW		MIL-STD-709
DELTA D.A.C.	RED		NONE		
AEROJET	NONE W YELLOW LETTERING		RED		
U.T.C.	BLUE		YELLOW		MIL-STD-709
THIOKOL	BLUE WHITE LETTERING	INERT	YELLOW		
ARMY MISSILE COMMAND	BLUE		NONE		AR-385-65 MIL-STD-709
NAVAL ORDNANCE TEST UNIT	YELLOW W BLACK STRIPE		RED		SAME AS POLARIS
SCOUT W.T.R.	LETTERED INERT	INERT	NONE		

figure 16

BLANK PAGE

BARRICADING AGAINST VENTED EXPLOSIONS

G. R. Cowan and F. M. Willis

Eastern Laboratory, Explosives Department,
E. I. du Pont de Nemours & Company, Inc, Gibbstown, N. J.

I. Introduction

An explosion is hazardous because of pressure and missiles. The purpose of a barricade is to reduce the blast pressure and missile velocities to levels required for prevention of injury to personnel and damage to structures. The barricade must be capable of withstanding the interior blast pressure so that the barricade itself does not become a source of injury. Barricade design must meet the two criteria of blast resistance and missile containment.

Two design problems arise: (1) the selection of the type of construction to provide reliable performance at minimum cost and (2) demonstration that the quantitative features of the selected type of construction give adequate protection. Experience has shown that the second question can be answered by scale model testing. In fact, a reliable quantitative design can often be based on tests at one particular scale, provided that due attention is given to any factors which lead to deviations from dynamical similarity. The first question is not easy to answer. However, it is clear that the nature of the loading of the structure by the explosion is a prime consideration. The blast pressures from explosives are in general extremely high, but of very short duration. Complete confinement of the explosion greatly extends the duration of the pressure, thus increasing the impulse per unit area applied to the barricade.

Neglecting short oscillations due to the initial blast and following reflections, the closed barricade is subjected effectively to the explosion pressure corresponding to the average loading density, applied suddenly and maintained with slow decay over a long duration, as discussed by Loving[1]. Thus full containment requires a very strong structure, and is impractical for large quantities of explosives. Fortunately, it is usually possible to vent the explosion quickly through an open or frangible light wall or roof, and still provide adequate reduction of blast pressure. In that case, the barricade is subjected to only a moderate impulse in spite of the high pressure; and if the response time of the barricade is very long, the strength of the barricade need not be high. Experience has shown that mounded earth or sand barricades are effective for large amounts of explosives stored in small rooms, i.e., at high average loading densities. When the roof thickness is adequate to keep the roof from rising more than its thickness, the earth walls sloped at the angle of repose are adequate to resist the blast with very little movement.

In many cases, especially in manufacturing facilities, the average loading density is low enough to make mounded barricades uneconomic and wasteful of space. In attempting to retain the long response time of the sand, one is led to consider a sandwich type of barricade. We have found that a structure consisting of dry sand supported between layers of corrugated steel decking held by steel I-beams constitutes an effective barricade against both blast pressure and missiles. Furthermore, in considering the action of such a structure, we have developed a simple mathematical model which predicts the behavior observed in

experimental tests. This model facilitates design of the prototype barricade as well as scale models. Figure 1 shows an example of this type of barricade being constructed for a manufacturing facility.

II. Scaling

Experience has demonstrated that the action of explosives can be scaled according to the principle of dynamical similarity, which combines geometrical similarity, in which all dimensions are scaled by a constant scale factor, S, with a scaling of the time t by the same factor S. Thus:

$$X' = SX, \quad t' = St$$

Dimensional considerations show how other quantities should scale. In particular, velocities are unchanged by scaling, as are pressure and stress; thus the characteristic blast pressure of the explosive and the strength properties of the barricade are independent of the scale. Acceleration (a) must be scaled inversely, i.e.,

$$a' \sim \frac{X'}{(t')^2} = \frac{SX}{(St)^2} = \frac{1}{S}\,a$$

To preserve dynamical similarity, the gravitational acceleration should be scaled by $\frac{1}{S}$. Since this is usually not practicable in scale testing, deviations from similarity may occur when the process depends on gravity. Such is the case for the height of rise of the roof of the barricade as a result of an explosion. On the other hand, the motion of the side walls in the case of relatively thin walls does not depend on gravity, but

only on the mass of sand and strength of the walls. Thus the scale tests accurately model the motion of the side walls.

The height of rise of the barricade roof requires special consideration. Because of rapid venting of the explosion, the effect of the explosion is to deliver a certain impulse to the roof in a very short time during which the upward displacement is negligible. The scale model roof thus is given an upward velocity, v, which is identical to the velocity of the full size roof. The height of rise, h, may be computed from the constant gravitational deceleration.

$$h = v^2/2g \qquad (1)$$

Therefore, $h' = h$, and the absolute value of height of rise is the same in the scale model as in the prototype. (Note that if gravity were scaled by 1/S, the height of rise would be scaled by S.)

In model testing, it is sometimes desirable to have the height of rise of the roof scale geometrically. This may be accomplished in the case of vented explosions simply by scaling the thickness of the roof, T, in the appropriate manner.

We require $h' = Sh$

Then $v' = (2gh')^{1/2} = (2gSh)^{1/2} = S^{1/2}v$

The impulse I given to the roof of area A, density ρ is

$$I' = \rho A'T'v' = S^3 I = S^3 \rho ATv$$

$$T'/T = S^3(A/A')(v/v') = S^3 \cdot S^{-2} \cdot S^{-1/2} = S^{1/2} \qquad (2)$$

The scaling of missile penetration is also important. As we shall discuss later, missile deceleration involves drag and static penetration strength. Drag scales according to dynamical similarity provided that the drag coefficient, C_D, is independent of Reynolds number. For blunt missiles, the drag coefficient is constant with a value of approximately 1 over a very large range of Reynolds number. Blunt missiles of moderate to high velocities are found to have a drag coefficient of unity in sand, so that missile penetration scales according to dynamical similarity. Minor deviations from similarity might be expected to arise from the dependence of the bulk strength of sand on the static pressure, which does not scale because it depends on the weight of sand above. However, the static strength is only effective in deceleration when the velocity is very low, in which case the outer decking can resist penetration.

III. Reaction of the Barricade to Loading

(a) Blast Loading

To facilitate barricade design, we need a quantitative description of the behavior of the barricade in resisting the blast loading. Let us first consider the behavior qualitatively with the aid of Figure 2. The blast wave loads the inner wall of decking to an extremely high pressure, far exceeding the strength of the decking, for a very short time. Thus a certain impulse per unit area is transmitted into the wall. If this impulse could be extended over a long time, it could be stopped by an outer wall of low strength capable of resisting a low

pressure for a long duration. Two steps will accomplish this desired action. Initially the impulse is associated with a small mass moving at high velocity, thus having a very large energy associated with it. If this impulse can be spread uniformly over a large mass, the velocity and the associated kinetic energy would be greatly reduced. Spreading of the impulse is opposed by the tendency exhibited by most materials to transmit the impulse as a shock wave that is weak in the sense that the expansion phase is almost the reverse of the compression phase; in this case there is little temporal spread of the impulse. However, in compactible porous materials, such as dry sand, which exhibit a large hysteresis between shock compression and expansion, the shock front is followed by a virtually uniform velocity extending to the inner wall. The second step involves the stopping of this large mass by the outer wall. If the outer wall is rigid, the shock front will be reflected back into the sand, and the kinetic energy of the sand will either be dissipated or remain as kinetic energy associated with a reversed velocity. The pressure to which the outer wall is subjected is the pressure behind a reflected shock that brings the sand to rest, and becomes higher compared to the incident shock pressure as the sand becomes less compressible ($\Delta P_r/\Delta P_i = \Delta V_i/\Delta V_r$). On the other hand, if the outer wall has a low modulus, e.g., by yielding plastically, the impulse can be resisted by a very low pressure acting for a long time. In this slow deceleration, there is little dissipation of energy in the sand, so that the outer wall must be capable of absorbing the kinetic energy of the sand.

The functions of the four elements of the structure are clear. The inner decking serves merely to contain the sand and to transmit the impulse from the reflected blast wave to the wall. The sand filler converts this impulse to the momentum of the whole thickness of sand moving at uniform low velocity, in the process largely dissipating the initially high energy delivered to the inner wall. The outer wall absorbs the kinetic energy of the sand at low pressure. The desired property of the outer wall is that it be able to sustain a low resisting pressure over a large displacement, in order to reduce the load applied to the I-beam structure. The corrugated decking is especially suitable because of its ability to undergo very large deflections without failure. The inner wall is attached only lightly to the I-beam structure, and is incapable of transmitting an appreciable outward load to the I-beams. Thus the I-beams need only be capable of withstanding the load associated with the maximum yield pressure of the outer decking. A blast overload cannot cause the I-beam structure to fail.

The foregoing qualitative analysis of the barricade response to blast loading may be readily quantified. We assume for the following discussion that the explosive charge or source of the blast is at a distance from the wall that is large compared to the thickness of the wall, and therefore we neglect geometrical spreading of the load in the wall - a point to be discussed in Part (b) of this section. The blast loading is then characterized

by the reflected impulse, I, delivered to the wall. Assuming the mass, w/g, of the wall is moving with uniform velocity, v, given by

$$(w/g)v = I \tag{3}$$

the kinetic energy, KE, of the wall is then

$$\begin{aligned} KE &= (1/2)(w/g)v^2 \\ &= (1/2)(g/w)I^2 \end{aligned} \tag{4}$$

The outer decking must be able to absorb the kinetic energy specified by Equation (4). The energy absorbing capacity may be specified in several ways. In making some scale model tests, we measured the energy absorbed in a static loading test of the decking. A panel freely supported at both ends was loaded by a central bar driven by the ram of the test machine at a fixed ram travel rate. The central deflection of the decking was recorded by a deflectometer to give a load deflection curve, shown in Figure 3. Timing marks were placed on the curve to indicate the corresponding ram travel. Integration of the load over the ram deflection gave the energy which was then plotted against the central deflection. This is shown in Figure 4 as E/D, energy absorbed per unit width of decking, D, versus d_c/L, the central deflection d_c per unit span L, a form which is independent of span and wdith and distribution of load in the plastic range, due to central buckling. An energy deflection curve can also be obtained from the manufacturer's data[8] and design formulas for uniform loading, taking the yield pressure P_y as twice the design pressure and using the formulas

$$E_e = (1/4)P_y d_y \tag{5}$$

for the energy E_e absorbed in the elastic range, where d_y is the central deflection at yielding and

$$E_p = (1/2)P_y(d_c - d_y) \tag{6}$$

for the energy E_p abosrbed in the plastic range for an assumed constant yield pressure P_y. The assumption that the average wall deflection is equal to half the central deflection inherent in these expressions is probably conservative in the elastic range and accurate in the plastic range due to the buckling nature of the yielding. As shown in Figure 4, the curve constructed from the manufacturer's data lies below the measured energy out to very large deflections.

A second energy deflection test was made in which the load was distributed over a layer of sand on the decking. With sand present, the energy absorption for given central deflection was approximately doubled. Presumably this is partly due to the effect of the sand in the deck channels impeding the buckling. Because of uncertainty as to whether the sand has a similar effect in the barricade and in the static test, we have used the energy curve without sand to be conservative. However, the higher maximum yield pressure obtained with sand should be used to determine the required strength of the I-beam structure. Additional blast or impact loading tests that are free of uncertainties in the exact impulse applied to the wall due to partial confinement of the charge by the floor and/or other walls should resolve this uncertainty in the effective strength of the outer decking.

The roof of the barricade does not require external decking, since gravitational deceleration will stop the initial upward motion. Again, assuming the sand has a uniform velocity, the height of rise h is

$$h = I^2 g/2W^2 \tag{7}$$

$$= (I/A)^2 g/2(w/A)^2 \tag{8}$$

where the second formula may be used for nonuniform loading, where I/A is the local reflected impulse per unit area and w/A is the weight of the roof per unit area.

(b) Loading by Large Missiles

It is often possible that accidental explosions will cause rather large missiles to be driven against the barricade walls. The lateral dimensions of such a missile may be of the same order as the thickness of the barricade wall. In such a case, the question is not one of missile "penetration" but rather it is whether the high local loading can punch out a section of the barricade wall. The situation is similar to that in which a substantial explosive charge is detonated at a position that is located at a distance from the barricade wall that is less than a few times the thickness of the wall. The loading on the inner surface of the barricade in terms of impulse per unit area may be very high. However, the sand-fill can spread the impulse not only in a direction perpendicular to wall but also in the transverse directions, thus spreading the load over a larger area of the outer decking. The process is undoubtedly complex in detail. We have used the following reasonable but arbitrary method for estimating the barricade response, illustrated in Figure 10.

The kinetic energy that must be absorbed by the outer decking is taken as the kinetic energy of the sand, assumed to behave as a one-dimensional channel flow of an incompressible liquid in a channel of increasing cross-sectional area A. Then

$$Av = C \tag{9}$$

where v is the velocity and C is a constant, which can be evaluated from the total impulse

$$I = \int_0^H \rho Avdh = \rho CH \tag{10}$$

$$C = I/\rho H \tag{11}$$

where H is the thickness of the barricade wall, and ρ is the density of the sand.

The kinetic energy is

$$KE = (1/2) \int_0^H \rho Av^2dh \tag{12}$$

$$KE = \frac{I^2}{2\rho H^2} \int_0^H \frac{dh}{A} \tag{13}$$

It is also assumed that the area increases at a 45° angle. The geometrical integral in Equation (13) can readily be evaluated for the particular missile shape, e.g.,

a. A circle of radius r_0 loads a circle of radius $r_0 + H$ on the outer wall with kinetic energy

$$KE = \frac{I^2}{2\pi\rho Hr_0(r_0 + H)} \tag{13a}$$

b. A square missile of side ℓ loads an outer square of side ℓ + 2H with a kinetic energy

$$KE = \frac{I^2}{2\rho H\ell\ (\ell + 2H)} \tag{13b}$$

c. A rectangular missile with dimensions ℓ_1 by ℓ_2 loads an outer rectangle with dimensions (ℓ_1 + 2H) by (ℓ_2 + 2H) with

$$KE = \frac{I^2}{4\rho H^2(\ell_1 - \ell_2)} \quad \ln \frac{(\ell_2 + 2H)\ \ell_1}{(\ell_1 + 2H)\ \ell_2} \tag{13c}$$

Experimental tests have indicated that the suggested method is slightly conservative, even on the center line of the missile. It appears likely that the load is not spread uniformly over the area assumed in the model, but this is compensated by further dissipation of kinetic energy in the sand as the outer decking brings the motion to rest.

IV. Missile Penetration

The problem of missile penetration is complex, especially when the question is posed in the following way. Given a particular missile of specified density, dimensions, and velocity, will it penetrate any particular barrier that may be constructed of one or more of a number of different materials? The difficulty is that there are different regimes of behavior, the one characterized properly by the word "penetration" being one in which the missile is capable of penetrating into a semi-infinite block of barrier material to a distance greater than the smaller transverse dimension of the missile. Thus a given missile may be in the penetration regime when striking sand, and be outside the penetration regime when striking steel. The latter case, typified by a low-velocity steel missile striking a steel sheet, is one of

transient local loading of a structure, with the possibility of excessive deformation leading to failure by tearing or shearing. The case of a large missile striking the sandwich barricade has already been considered in Section III-b.

It is our opinion that the penetration can be described by a general formula valid for any barrier as long as the missile velocity is high enough in relation to the pertinent properties of the barrier, and provided the missile is harder than the barrier. The formula is an old one suggested by Euler[2] and bearing the name of Poncellet[3], which has often been used without proper attention to the constants involved. The equation may be derived [4] from a missile deceleration equation containing a drag resistance and a static resistance:

$$-dv/dt = (C_D \ \rho/2m)v^2 + P_O m \tag{14}$$

where v is the missile velocity, C_D is the drag coefficient, m is the mass of the missile per unit area, ρ is the density of the barrier material, and P_O is the static penetration strength of the barrier. The penetration S into the barrier, in terms of the initial velocity V, is

$$S = (m/\rho C_D) \ \ln \ [1 + (C_D \rho/2P_O)V^2] \tag{15}$$

For blunt missiles the drag coefficient C_D is taken as unity. This formula has been found to agree with experiment for steel missiles penetrating sand and steel missiles penetrating steel (described in Section VI), with P_O = 145 psi for sand and P_O = 145,000 psi for steel. P_O is essentially the "hardness" of the material, the value for steel being taken from the diamond pyramid hardness number, converted to the appropriate units of stress.

In estimating the resistance to missile penetration of the decking/sand/decking barricade, we have considered the sand to be the primary missile stopper. For very high-velocity missiles, the inner decking will not have much effect, whereas the sand itself is highly effective because of the drag term. The effect of the outer decking is likely to be equivalent to raising the static strength (P_0) of the sand. Measurements of slow penetration into sand indicate a strong dependence of P_0 on the hydrostatic pressure, ranging from about 20 psi at 0 psig to about 300 psi at 2.5 psig. Since there will generally be an appreciable hydrostatic pressure, especially in the lower parts of the barricade walls, due to the head of sand, the correct value of P_0 may be several hundred pounds/square inch. For high-velocity missiles, the penetration does not depend strongly on P_0.

In the case of somewhat lower velocity missiles that still fall in the penetration regime for sand, the inner and outer decking will have an appreciable effect on the penetration rating. At the present time, we do not have enough experimental data to justify a systematic allowance for the stopping power over that of the sand alone.

V. Blast Output and Missile Velocities

In the foregoing discussion, we have assumed that the blast wave and missile sizes and velocities that load the barricade structure were specified. Given an explosive weight and configuration, and the configuration of surrounding materials, the

problem of estimating the loading on various portions of the barricade by blast and missiles is often complex and subject to uncertainties. There are adequate experimental measurements of reflected impulses from blast waves generated by bare explosive charges impacting a single flat wall [5]. However, the effect of partial confinement by neighboring walls and floor is complex and has not been well studied. We have observed that if the explosive is relatively closer to one wall, the peak impulse per unit area imparted to that wall is little affected by reflections from the other walls; the confinement of the other walls does tend to cause the impulse per unit area to be applied nearly uniformly over the wall. The effect of reflections from close walls and floor on the blast loading of walls or roof farther from the charge may cause the impulse to be increased by up to a factor of 2. The compendium of charts showing the calculated effects of wall reflections presented by Saffian[5] should prove useful in estimating the blast loading in any particular configuration.

The high-velocity missiles that are usually hardest to contain are generated by materials such as steel that are in close contact with the explosive. The velocity of these missiles can be estimated from the Gurney[7] formula. If an empirical value for the Gurney energy is not available, this quantity may be taken as 60% of the Q or heat of explosion.

VI. Experimental Tests

(a) Response of Model Barricade to Blast Loading

A scale model of a proposed manufacturing facility

barricade was constructed at 1/3 linear scale (see Figures 5 and 6).

1. Explosive charge

a. Weight 20 lb TNT x $(1/3)^3$ = 3/4 lb TNT

b. Location 5 ft 3 in. (1/3) = 21 in. from wall, 3 ft (1/3) = 12 in. from floor

2. Building dimensions

a. (25 ft x 15 ft 6 in. x 18 ft) 1/3 = 8 ft 4 in. x 5 ft 2 in. x 6 ft

3. Roof sand cover (24 in.) 1/3 = 8 in. sand

4. Wall (two sections decking plus I-beam)

a. (24 in. sand + 2 (4-1/2 in.) decking) 1/3 = 8 in. sand + 2 (1-1/2 in.) decking

b. (4.0-in.^{3} section modulus roof deck) $(1/3)^3$ = 0.148 in.^{3} Section modulus actually used 0.184 in.^{3}

Two wall sections were constructed of two layers of decking supported by I-beams and filled with dry sand. The decking was selected to match as closely as possible the scaled section modulus and thickness of the prototype decking. The two wall sections were placed directly opposite to each other to enable a rigid tying together to prevent motion of the I-beams in the ground. The remaining portions of wall were constructed of massive sand-filled boxes to provide similar confinement of the blast. The roof was constructed of a light frame and plywood panel supporting the scaled thickness of sand. Dynamic deflections were measured on both walls by pin sets located at the height of the charge.

Permanent deflections were measured at the same locations. The height of rise of the roof and general barricade response was observed by high-speed photography.

For the purpose of this paper, we shall discuss the reference shot made with TNT, although the barricade was designed for and tested with other explosive materials.

Prediction of Wall and Roof Motion
in 3/4-lb TNT Scaled Test

Charge weight W = 3/4 lb TNT, equivalent to 3/4 lb pentolite. Pentolite was the explosive used by Hoffman and Mills[5] in measuring the blast impulse against a wall. Distance from charge to nearest wall d = 21 in. = 1.75 ft. Scaled distance

$$z = \frac{d}{W^{1/3}} = 1.93 \text{ ft/lb}^{1/3}$$

from Figure 4 of Hoffman and Mills,

$$\frac{\text{Impulse}}{\text{Area } W^{1/3}} = \frac{I}{AW^{1/3}} = 85 \text{ psi ms/lb}^{1/3}$$

$$I/A = 0.085 \times 0.9085 \times 144 = 11.1 \text{ lb-sec/ft}^2$$

The charge is directly opposite an I-beam, so that the impulse is not delivered uniformly over the nearest test wall. However, we shall assume that the reflections from the other walls can be approximated by assuming that a uniform impulse is applied over the whole wall with a strength given by direct impact at d = 1.75 ft. The weight w of the wall, per unit area A, is

$$w/A = 100 \text{ lb/ft}^2$$

Assuming that the sand is effective in spreading the impulse uniformly over the full thickness of the wall, the kinetic energy (KE) per unit area is

$$\frac{KE}{A} = \frac{1}{2}\left(\frac{I}{A}\right)^2 \frac{gA}{W} = \frac{1}{2}\ \frac{(11.1)^2 32.2}{100}$$

$$= 19.8 \text{ ft-lb/ft}^2 = 238 \text{ in.-lb/ft}^2$$

For a span L = 3 ft, the energy per unit width E/D = 714 in.-lb/ft. From the energy/deflection curve based on the manufacturers' data, the predicted permanent deflection per unit span is d_c/L = 0.34-0.07 = 0.27 in./ft, giving d_c = 0.81 in. The corresponding value obtained from the static test curve in Figure 4 is d_c = 0.64 in. The explosion produced a maximum deflection of 0.48 in., with the deflection being almost the same over several panels. This confirms the assumption that the partial confinement produces a uniform impulse per unit area equal to the maximum value with no confinement. The fact that a slightly conservative value is predicted by the static test without sand indicates that the presence of sand does tend to impede buckling.

The recovered deflections may be obtained by subtracting the permanent deflections from the dynamic deflections. On both test walls the values are about 0.20 in., corresponding to d_c/L = 0.07 in. This recovery is larger than that given by the computed energy/deflection curve, but agrees more closely with the measured curve. (In the elastic range the energy/deflection curve will be slightly different for central loading as in the

static test than for uniform loading in the shot. In the plastic range little difference between the curves for uniform and central loading are expected, because of the buckling that occurs in yielding.)

<u>Calculation of Roof Motion</u>

$$d = 50 \text{ in.} = 4.17 \text{ ft}$$

$$z = \frac{d}{W^{1/3}} = \frac{4.17}{0.9065} = 4.6 \text{ ft/lb}^{1/3}$$

From Hoffman and Mills

$$\frac{I/A}{W^{1/3}} = 35 \text{ psi ms/lb}^{1/3}$$

$$I/A = 4.58 \text{ lb-sec/ft}^2$$

The weight of the roof per unit area is

$$w_r/A = 67 \text{ lb/ft}^2$$

If the effect of partial confinement is neglected, the predicted average initial roof velocity v is

$$v = \frac{I/A}{w_r/gA} = \frac{4.58 \times 32.2}{67}$$

$$= 2.20 \text{ ft/sec}$$

The predicted height of rise h is

$$h = v^2/2g = 0.075 \text{ ft} = 0.9 \text{ in.}$$

The observed rise was about 3-4 in. (see Figure 7). By applying a factor of 2.0 to the impulse due to the partial confinement, the predicted height will coincide with the observed height.

$I/A = 9.16$ lb-sec/ft^2

$v = 4.40$ ft/sec, and

$h = 0.30$ ft $= 3.6$ in.

The impulse is slightly less than that computed for the near wall. Previous tests in which wall movement was measured both with and without partial confinement indicated an impulse increased by a factor of 1.8 due to partial confinement. As noted above, the increase in impulse is expected to be higher on a wall or roof that is farther away from the charge.

Predicted Behavior of Full-Scale Barricade

Using the measured behavior in the small-scale TNT shot as a basis for estimating the effect of confinement on the blast pressure, we can compute the expected motion of outer walls and roof in a full-scale shot of 20 lb of TNT in the full-scale barricade (see Figure 8).

As discussed above, the height of rise of a scaled roof is expected to have the same absolute value in both the prototype and model for the case of a vented explosion. The predicted roof rise resulting from a full-scale explosion of 20 lb of TNT is 3-4 in.

The blast impulse on the near side wall, and in the other walls, in the full-scale prototype may be obtained by scaling the values for the 1/3-scale test shot. The impulse per unit area (I/A) on the opposite wall was found in the scale test to be approximately equal to that on the near wall, due to the reflection of the blast, especially from the near wall. The control wall

would be expected to receive an I/A of the same strength. The weight per unit area (w/A) of all sections of the barricade walls are essentially identical, with the value

$$w/A = 230 \text{ lb/ft}^2$$

From the smothering action of the sand, we can determine the kinetic energy of the walls moving with an assumed uniform velocity. Since I/A scales by the scale factor

$$I/A = 3(11.1) = 33.3 \text{ lb-sec/ft}^2$$

$$\frac{KE}{A} = \frac{1}{2} \frac{(I/A)^2 g}{w/A}$$

$$= \frac{1}{2} \frac{(33.3)^2 \, 32.2}{230} = 77.7 \text{ ft-lb/ft}^2$$

$$= 933 \text{ in.-lb/ft}^2$$

This energy must be absorbed by elastic and plastic deformation of the outer roof decking. The spans differ in different sections of the barricade. The deformation in each case can be computed from the yield pressure P_y and the energy requirement given above, using the equations given in Section III. From the specified values of the section modulus, Z, we have the manufacturer's[9] formulas for design pressure P_d and the pressure P_c at which the deflection is 1/360 of the span:

$$Z = 4.0 \text{ in.}^{-3} \quad P_d(\text{lb/ft}^2) = \frac{54660}{L^2}$$

$$P_c(\text{lb/ft}^2) = \frac{550,600}{L^3}$$

The calculated deflections of the outer surfaces of the various wall sections resulting from a 20-lb shot of TNT are shown in the following table.

Section Modulus Z	Span L (ft)	Yield Press P_y (psf)	Yield Deflection d_y (in.)	Elastic Energy E_e (in.lb/ ft^2)	Plastic Energy E_p (in.lb/ ft^2)	Permanent Deflection $d_c - d_y$ (in.)	Permanent Deflection $\frac{d_c - d_y}{L}$ (in./ft)
4.0	11.67	804	0.904	181	752	1.87	0.160
4.0	9	1350	0.536	181	752	1.11	0.124
4.0	6.42	2650	0.273	181	752	0.57	0.088

The panel with the longest span gives the largest computed plastic deflection, 1.87 in.; however, the relative deflection d/L is only 0.16 in./ft, which, as indicated in Figure 2 for the small-scale decking, is below (by more than a factor of 4) the deflection at which failure could occur due to reduction of the strength below the static design level.

(b) Response of Model Barricade to Loading by Large Missiles

In order to validate the method presented in Section III-b for estimating the lateral spreading of the impulse when the inner wall is loaded locally by a large missile, two tests were made of the response of the scale-model barricade described in VI-a to square metal plates driven by sheet explosive charges. Equation 13b was used to obtain the kinetic energy that is absorbed by outer decking of span L = 3 ft and width ℓ + 2H, with H = 0.833 ft taken as the average thickness of sand.

In Test 1 the missile was a 4-in. x 4-in. x 1/16-in. steel plate weighing 0.284 lb driven at a velocity of 2230 ft/sec and thus imparting an impulse of 19.7 lb-sec to the

barricade. The kinetic energy of 1130 in.-lb loaded a 3-ft span of outer decking 2 ft wide to 565 in.-lb/ft. From the measured energy deflection curve for central loading of the steel decking, the predicted maximum deflection is about 0.65 in. and the permanent deflection is 0.45 in. From the manufacturers' data the maximum deflection is about 0.72 in. and the permanent deflection is 0.63 in. In the experiment, the missile punched a clean hole through the inner decking and produced a transient deflection between 0.36 in. and 0.60 in., with a permanent deflection of about 0.1 in. In Test 2 the missile was a 6-in. x 6-in. x 1/8-in. steel plate weighing 1.28 lb driven at a velocity of 1330 ft/sec, imparting a calculated energy per unit width of outer decking of 2300 in.-lb/ft. This is off the scale of the experimental energy deflection curve for central loading; from the manufacturer's data the predicted permanent deflection is 2.7 in. In the test, the missile punched a clean hole in the inner decking, and produced a permanent deflection of the outer decking of 2.3 in.

These tests indicate that the method proposed for estimating the lateral spread of the impulse in the barricade is valid, and that the use of the energy-absorbing capacity of the steel decking without sand is conservative. An example of a barricade for a manufacturing facility in which the hazard of a large missile determined the design parameters is shown in Figure 9.

(c) <u>Penetration Tests</u>

A test was made to determine the penetration of high-velocity missiles into dry sand. The missiles were generated by detonating a high explosive charge filling a 2-in.-ID x 5-in.-OD x 8-in.-long steel cylinder. The missile velocity was measured by electric pin contacts and was found to agree with the velocity calculated from the Gurney formula, which was V = 1450 ft/sec. Many of the recovered missiles were 1.5 in. thick, corresponding to a weight per unit area of 0.42 lb/in.^{2}. The density of the sand was 100 lb/cu ft. The maximum observed penetration was 3.25 ft. The penetration calculated from Equation 15 using $C_D = 1$ and $P_0 = 43$ psi for the static strength of sand is 3.37 ft. If P_0 is taken as 145 psi, corresponding to that measured for loading by a head of 1.7 ft, the calculated penetration is 3.12 ft.

The applicability of the penetration formula to the penetration of high-speed steel missiles through steel plates was checked against a penetration experiment in which cylinders of varying thickness were exploded inside an open box with steel sides with thicknesses of 1/4 in., 1/2 in., 3/4 in., and 1 in. The missile velocities were calculated from the appropriate Gurney formula, and the calculated penetration was obtained from Equation 15 using the value $P_0 = 145{,}000$ psi corresponding to the diamond pyramid hardness number. The "measured" values indicate the estimated plate thickness that would just allow penetration by the specified missiles, based on observations of the degree of penetration observed in the various combinations. It is well to note that a missile can penetrate a barrier

that is somewhat thicker than the penetration distance into a very thick barrier. The comparison is shown in the following table.

Missile Thickness	Velocity	Penetration Calculated	"Measured"
1/8 in.	9000 ft/sec	0.428 in.	~1/2 in.
1/4 in.	6510 ft/sec	0.696 in.	~3/4 in.
3/8 in.	5450 ft/sec	0.897 in.	Almost 1 in.
1/2 in.	4710 ft/sec	1.11 in.	More than 1 in.

VII. Summary

A sandwich structure of dry sand contained between walls of corrugated steel decking supported by steel I-beams has been shown to be an effective barricade against blast and missiles from a vented explosion. A simple, systematic method has been developed for designing the barricade walls against blast loading, intense localized loading by large missiles, and penetration by high-velocity missiles. A similar method describes the response of a sand-covered roof without external decking, which is applicable not only to the case of moderate explosive loading densities for which the sandwich walls are appropriate but also to the case of very high explosive loading densities for which a mounded barricade is appropriate. The scaling of roof motion has been accounted for. Experiments have shown that the method of design using statically determined properties is valid and slightly conservative. A missile penetration formula based on static properties has been shown to be valid for penetration of steel missiles into sand at moderate velocities and for penetration of steel missiles into steel at high velocities.

ACKNOWLEDGMENT

Many colleagues at Eastern Laboratory have contributed to this work. J. P. Swed, J. W. Edl, and W. J. Simmons carried out several of the experimental tests. We have benefited from discussions with our fellow members of the Eastern Laboratory Barricade Committee, C. J. Breza and J. P. Swed. F. H. Kenton and R. P. Delano, of the Engineering Department, suggested the sandwich barricade for a particular application, and thereby supplied the impetus for this work. We thank C. O. Davis for his interest and support, as well as for discussions which were especially valuable because of his considerable experience in this field.

REFERENCES

1. Loving, F. A., Ind Eng Chem, 49, 1744 (1957).
2. Euler, L., "Neue Grundsätze der Artillerie", Berlin; reprinted as "Euler's Opera Omnia" (Druck und Verlag Von B. G. Teubner, Berlin, 1922), First Edition, p 450.
3. Poncellet, J. V., "Cours de Mécanique Industrielle (1829); Mem Acad d' Sciences 15, 55 (1835).
4. Allen, W. A., Mayfield, E. B., and Morrison, H. L., J Appl Phys, 28, 370 (1957).
5. Hoffman, A. J. and Mills, S. N., Jr, Ballistic Research Laboratories Report No. 988 (1956); Goodman, H. J., Ballistic Research Laboratories Report No. 1092 (1960).
6. Wachtell, S. - paper presented at this Seminar.
7. Gurney, R. W., BRL Report No. 405 (1943); Sterne, T. E., BRL Report No. 648 (1947).
8. Macomber, Inc, Canton, Ohio, "Structural Decking".
9. H. H. Robertson Company, Pittsburg, Pa, "Structural Decking".

Figure 1

Typical sandwich-type construction showing corrugated steel roof decking and I beam construction. (United States Army photograph)

FIGURE 2

BEHAVIOR OF BARRICADE TO BLAST LOADING

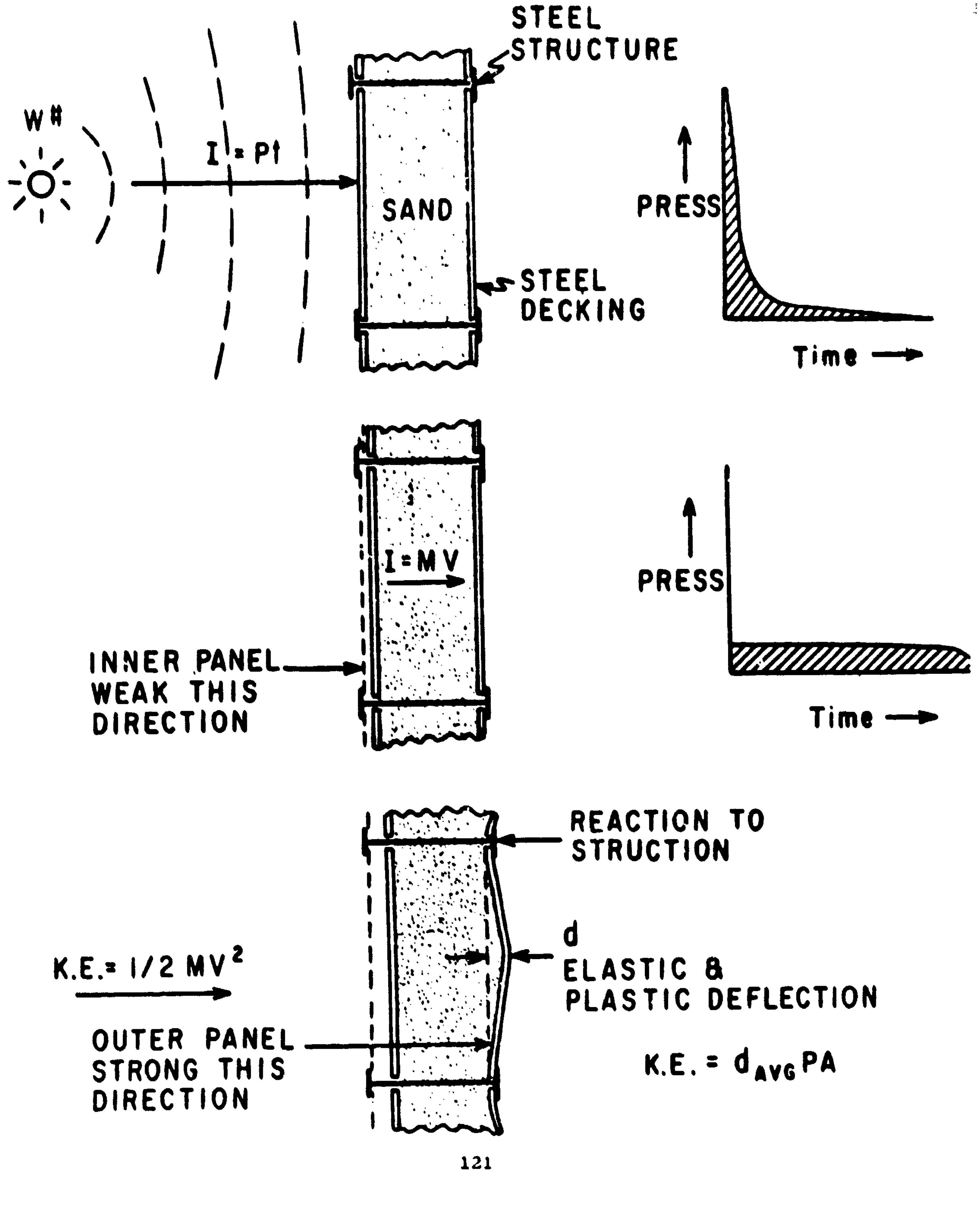


FIGURE 3

LOAD VS. CENTRAL DEFLECTION

COPY OF TEST RUN ON RIEHLE UNIVERSAL TESTING MACHINE AT EASTERN LABORATORY

MACOMBER TYPE W-20 ROOF DECK, 19 IN. WIDE, 22.75 IN. SPAN, I=0.181, Z=0.184

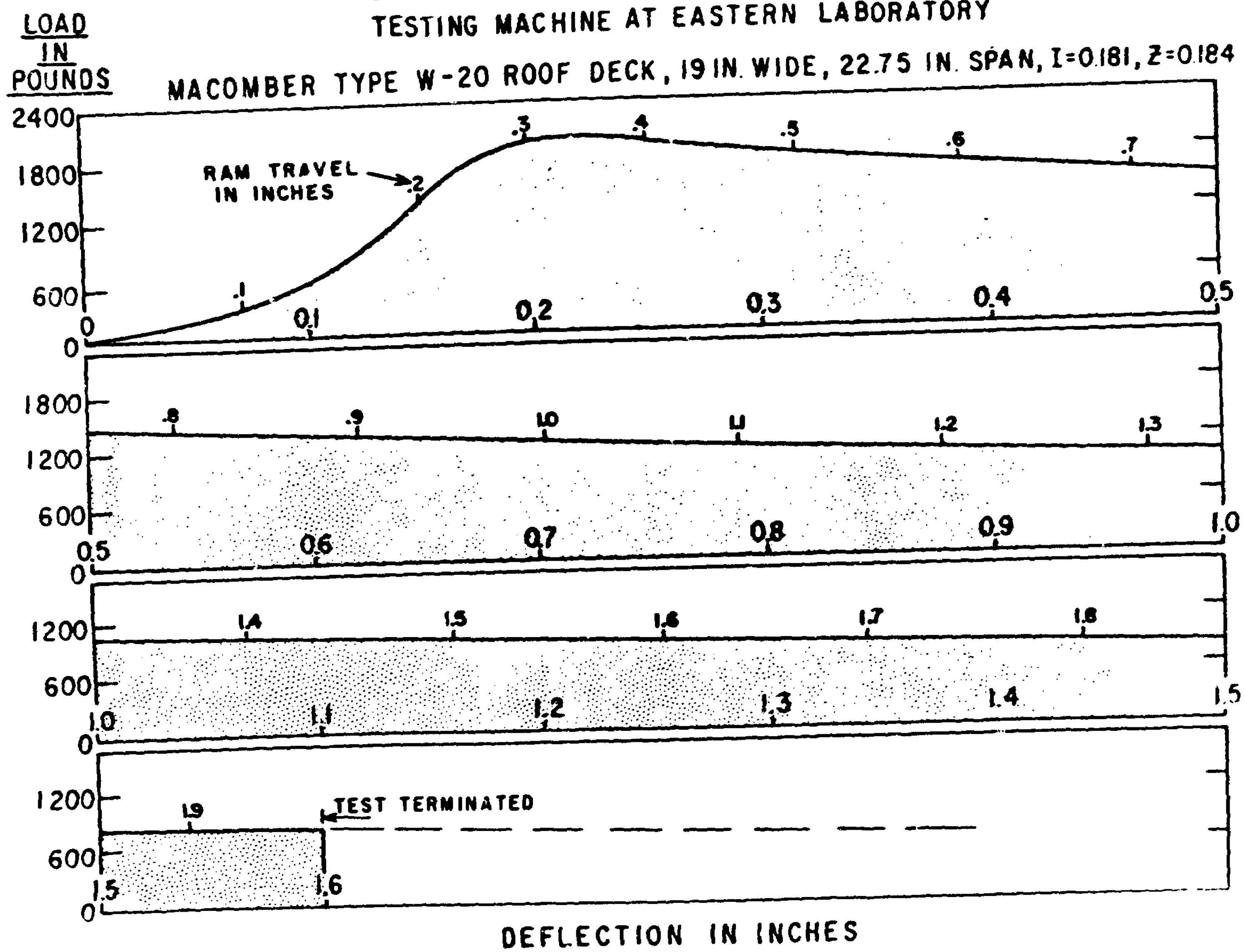


FIGURE 4

SMALL SCALE ROOF DECK STATIC TEST ENERGY CURVE FOR CENTRAL LOAD MACOMBER ROOF DECK TYPE W-20

1-1/2" DEEP #20 GA STEEL Z = 0.184; I = 0.181

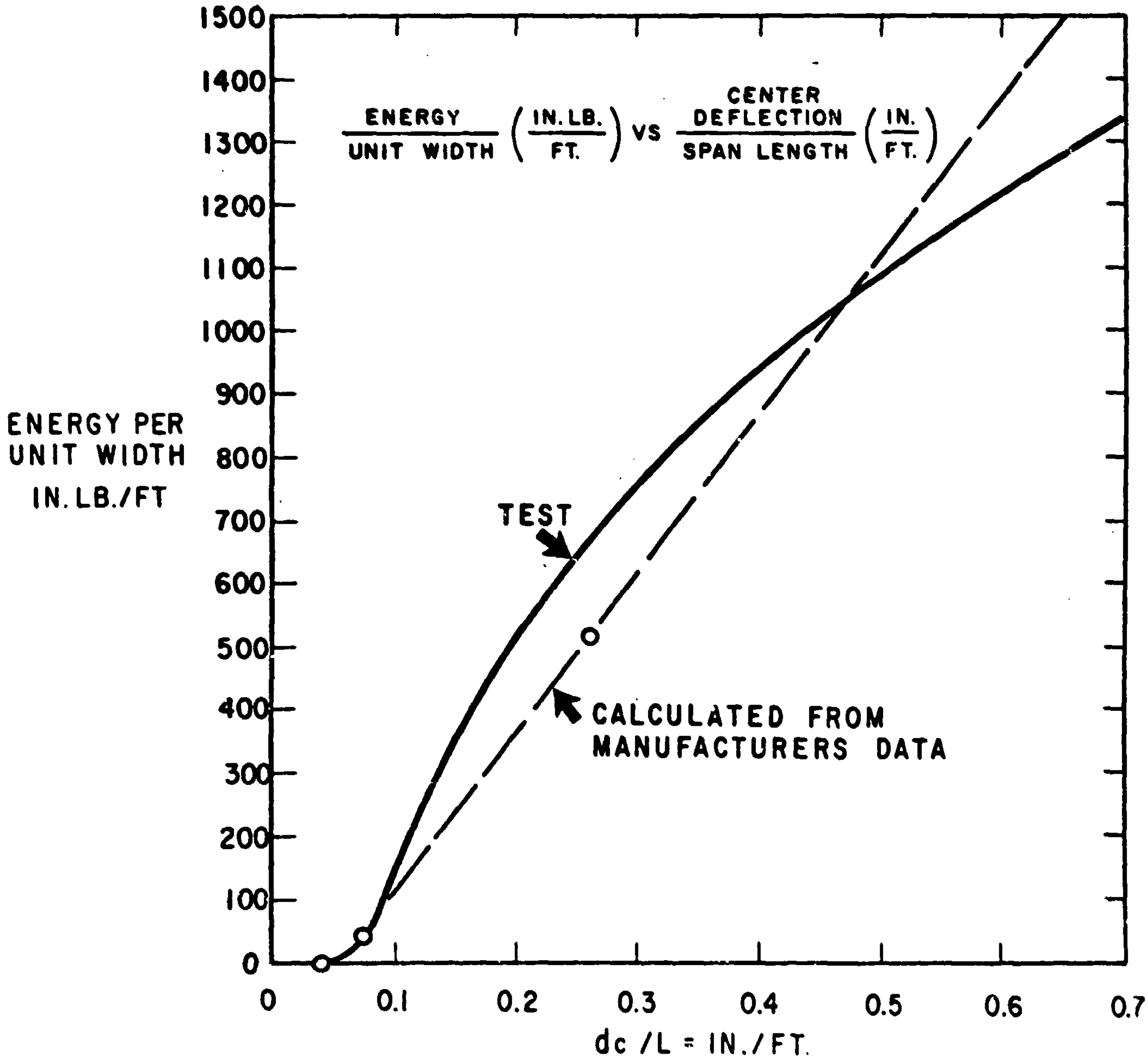


FIGURE 5

PLAN VIEW 1/3 SCALE TEST

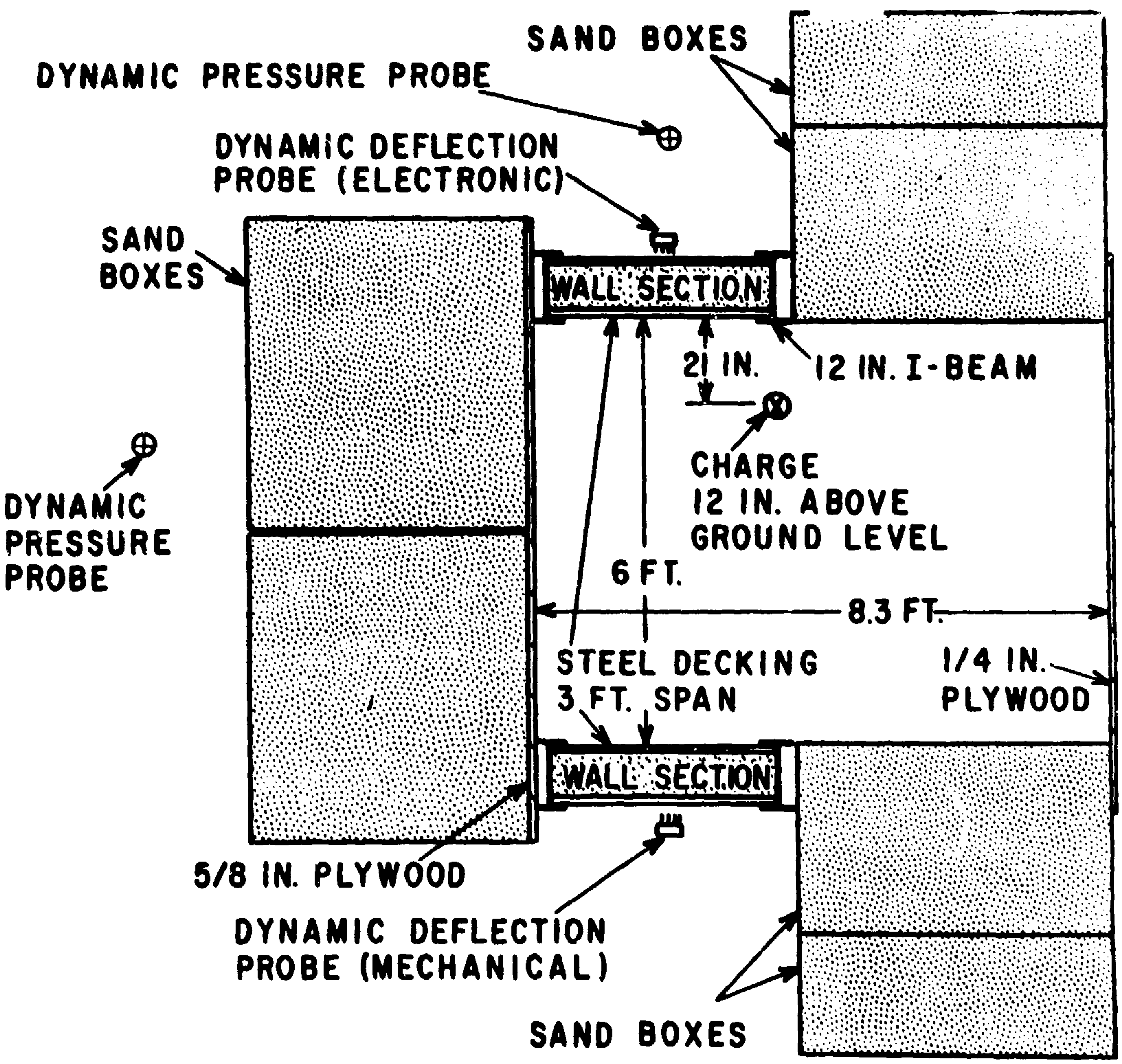
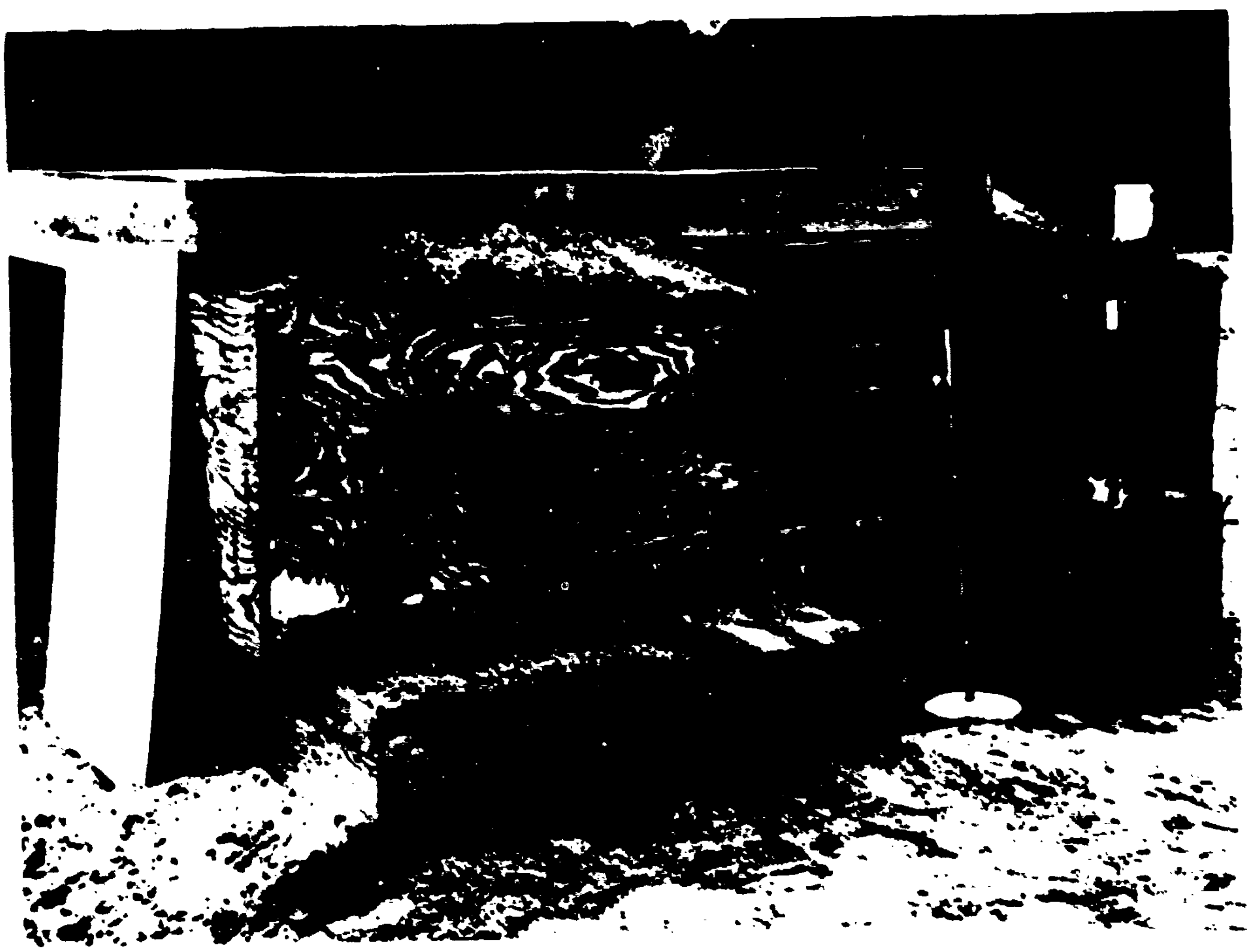


Figure 6



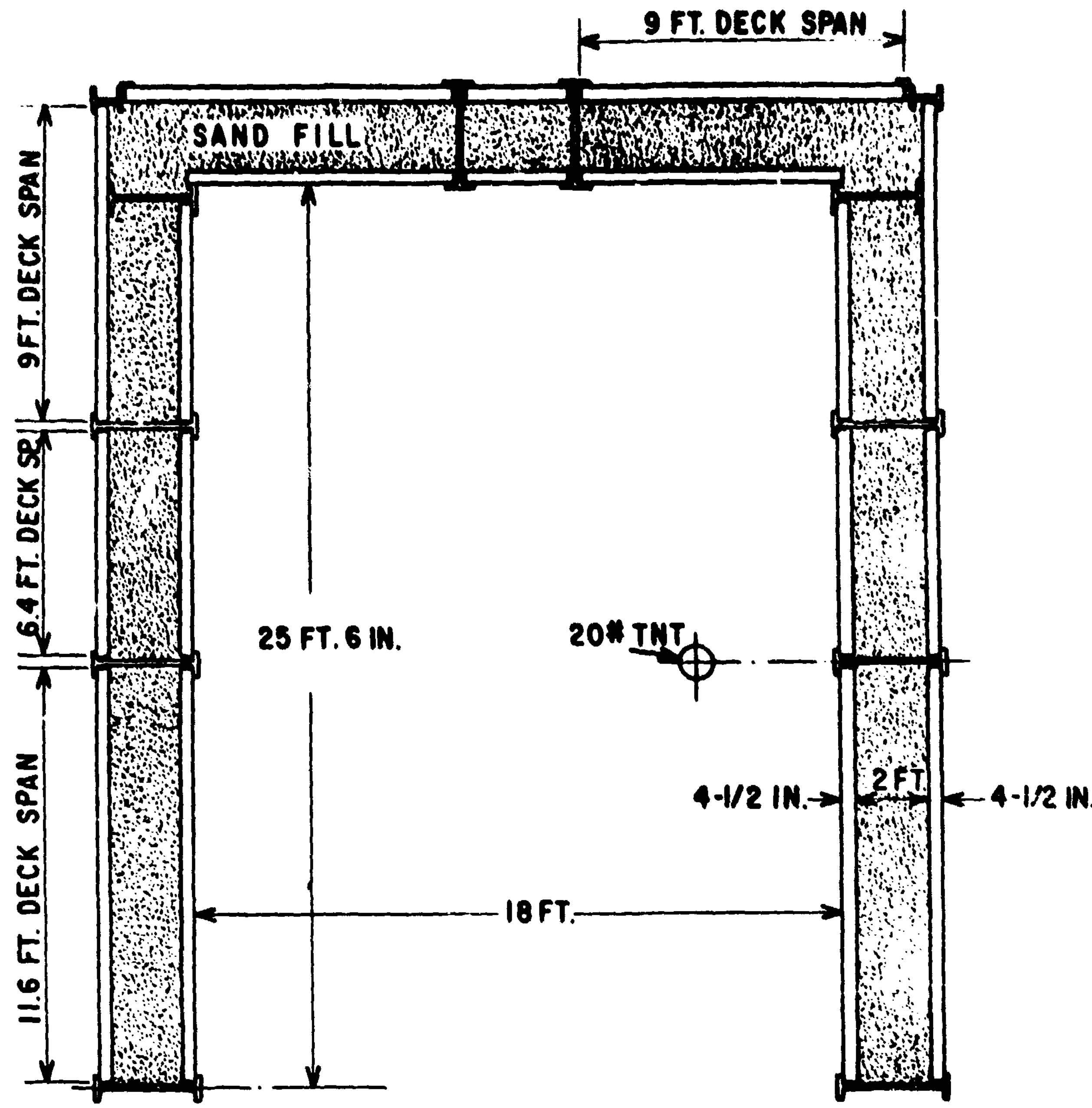
Scale model before test showing scale roof deck wall panel, sand roof cover box, and sand-filled wall improvization.

Figure 7

3/4-Pound TNT test showing peak roof rise, frangible vent wall panel flying, and Fastax photography setup.

FIGURE 8

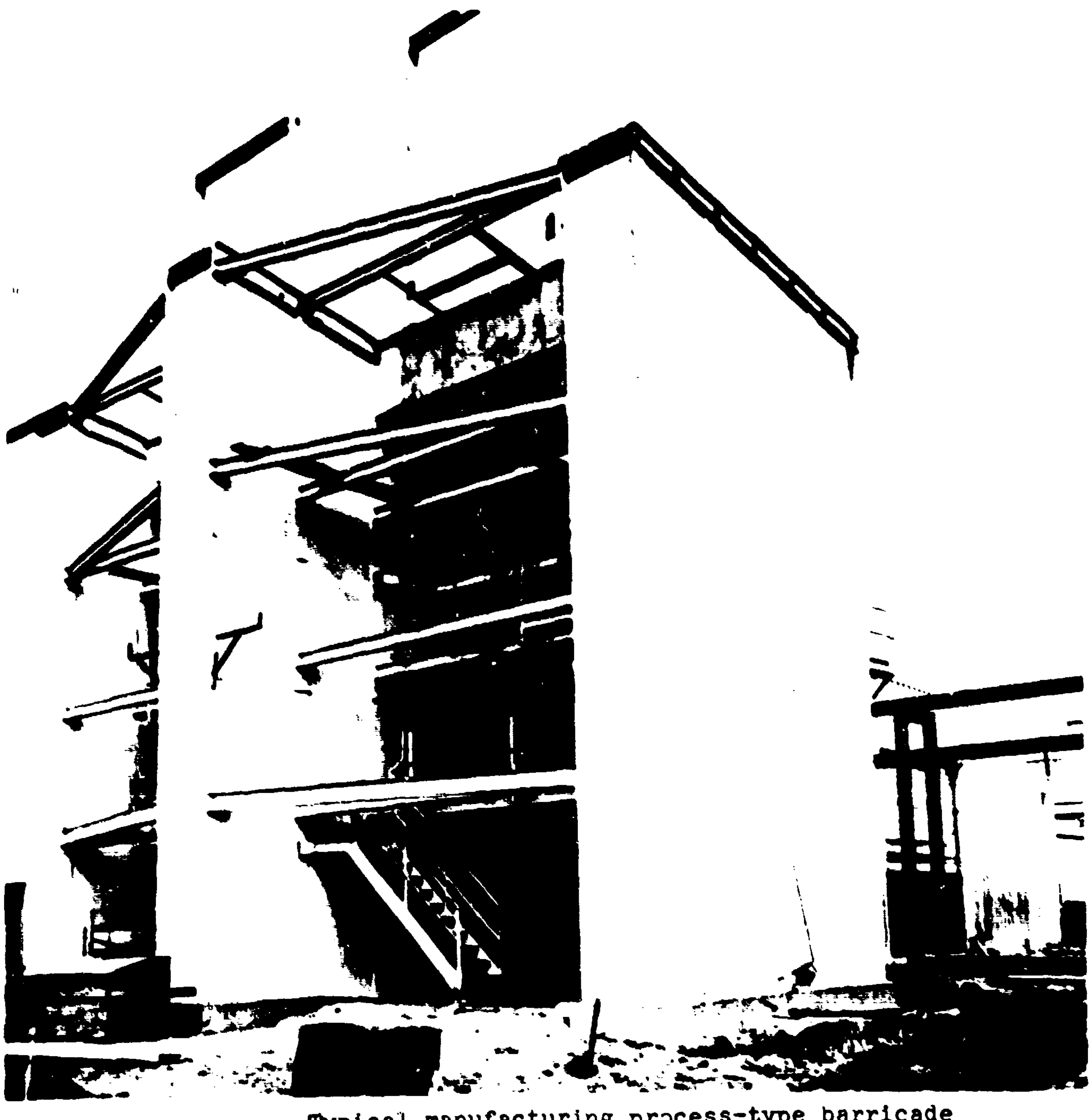
FULL SCALE BARRICADE



PLAN VIEW

SECTION

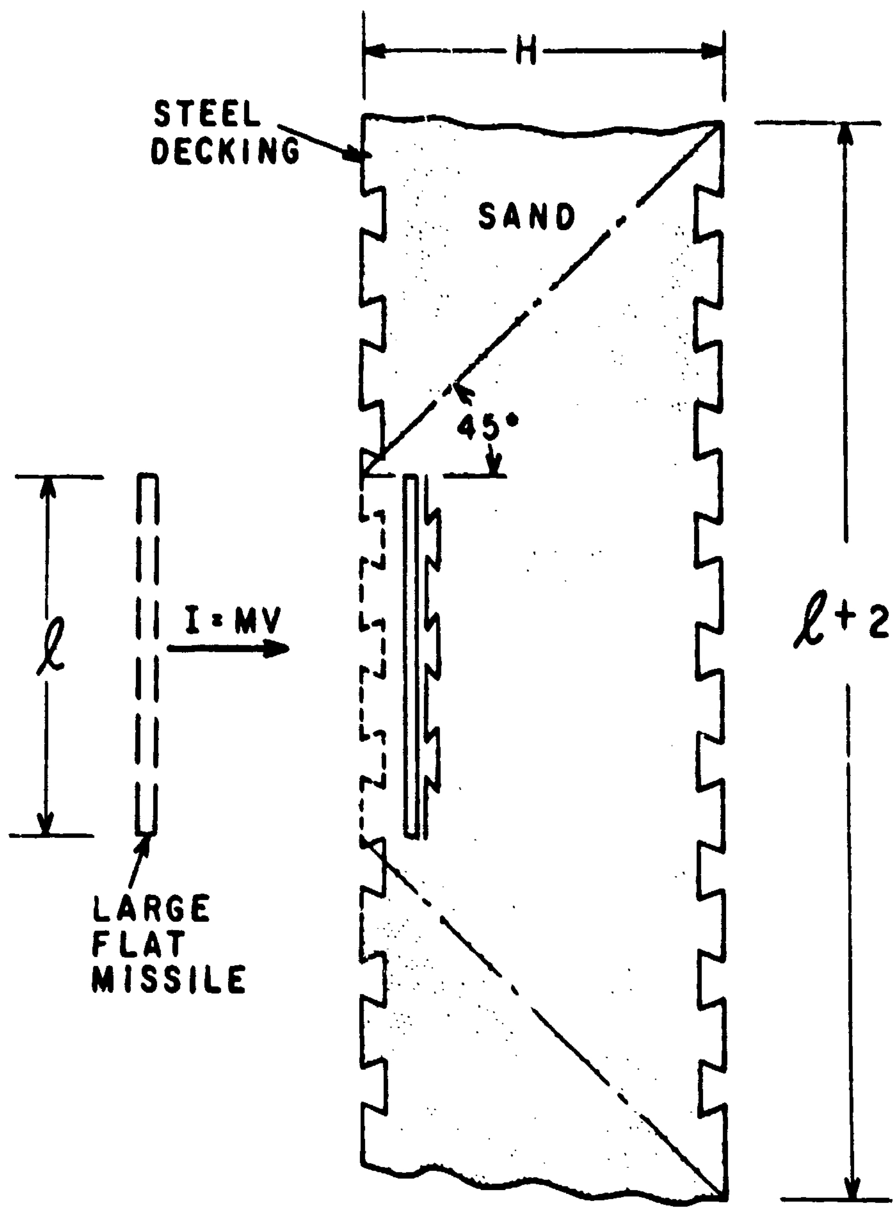
Figure 9



Typical manufacturing process-type barricade of sandwich construction, 3 feet of sand, plus 9 inches of roof deck approximately 30 feet high.

FIGURE 10

BEHAVIOR OF BARRICADE TO LARGE FLAT MISSILE LOADING



BLANK PAGE

AIR FORCE EXPLOSIVES ACCIDENT PREVENTION PROGRAM

by

Donal E. Endsley
Directorate of Aerospace Safety
Norton Air Force Base, Calif.

Figure 1

Ladies and gentlemen, Col. Biretta, my boss and the Air Force Member of the Armed Services Explosives Safety Board, regrets that he was unable to attend this seminar. He had eagerly looked forward to meeting with you and discussing mutual problems in the explosives safety business. However, an unforeseen commitment came up which he could not defer.

Therefore, I stand ready, as his Deputy, to lend every assistance possible, in the successful conduct of the various sessions of this seminar for which the Air Force has a corollary safety role. Where conflicts of time occur, LTC Perris, the Alternate Air Force Member of the ASESB, Mr. Henderson of Col. Biretta's office, and representatives from major commands will assist in covering the Air Force participation in the various sessions.

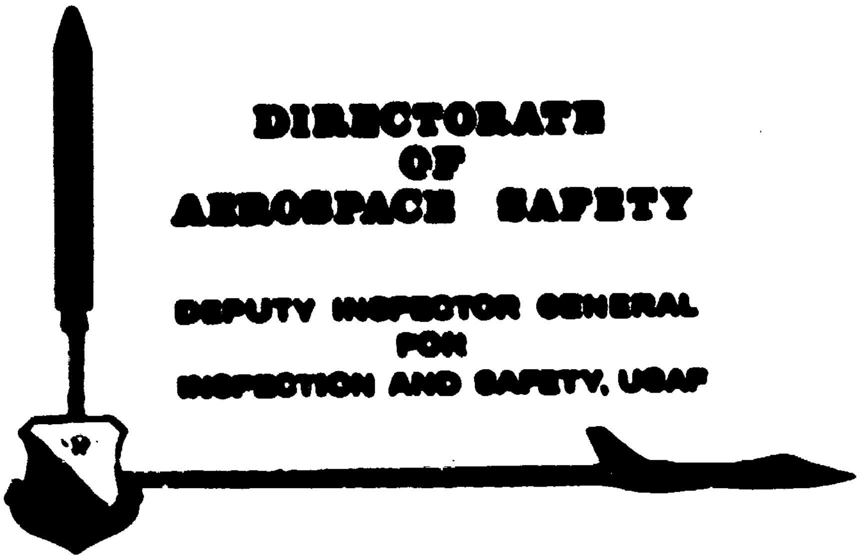


Figure 2

Before I start briefing you on the Air Force Explosives Safety Program, I would like to give you an insight into our organization and its relationship within the Air Staff. Due to our geographical location at Norton AFB, many agencies who are not familiar with the Air Force organization do not readily associate our function with the Air Staff.

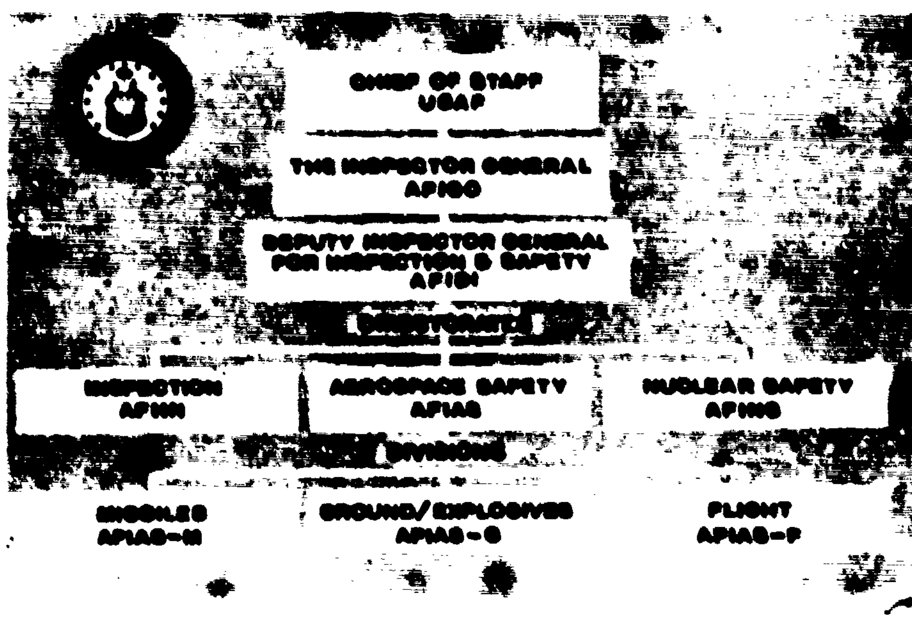


Figure 3

As most of you are aware, at the top of this chart we have the Chief of Staff, General McConnell. His Inspector General is Lt Gen Moore. These offices are located in the Pentagon. Now, moving westward to California, Maj Gen Hunziker is the Deputy Inspector General for Inspection and Safety. He has the three Directorates indicated. All of these Directorates and Divisions are located at Norton AFB, San Bernardino, California, with the exception of the Directorate of Nuclear Safety which is located at Albuquerque, New Mexico.

Explosives Safety is under the Director of Aerospace Safety, Brig Gen Frank K. Everest, Jr., affectionately referred to as "Speedy Pete" or the fastest man in the Air Force. He earned this title while serving as a fighter test pilot.

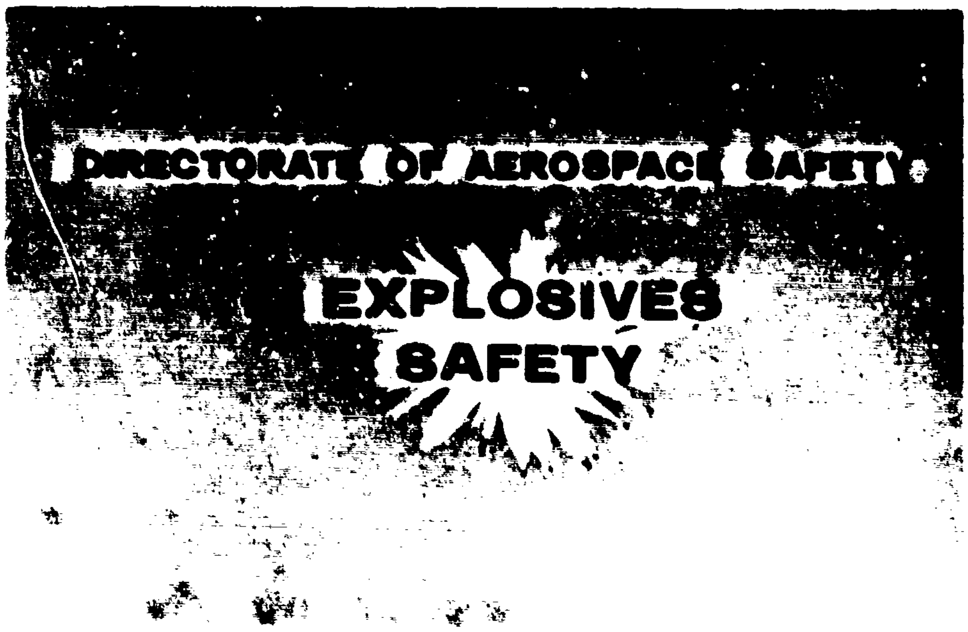


Figure 4

Now, moving into our problems and programs of mutual interest. First - I would like to give you an insight into what effect the national policy has had on our program in terms of: (1) Munitions Buy Program, and (2) Accident Data.

Secondly - I would like to brief you on some of the significant accomplishments within the past year which should assist in compensating for the vast and sundry array of munitions entering the Air Force inventory.

Third - and by no means the least - what you can do to assist us in saving lives and essential Air Force material.

Problem today - to fully appreciate the magnitude of the problem as it exists today on our airdromes in CONUS and overseas, we should recall the evolution of significant changes that have occurred during the past few years.

Figure 5

In the pre-1950 time period our conventional munitions were safely nested in bunkers in remote storage areas which posed little or no threat to lives and operational resources.

In the 1950-60 time period a few conventional munitions items emerged from hibernation in support of the rapid response capability. Thus, for the first time, explosives items were in a hostile environment - the flight line - and explosives safety was no longer academic to the safety man's job.

Due to this evolution, the Air Force Explosives Safety Manual and Technical Orders were developed to assist in coping with this new and changing situation.

The next significant change occurred in 1961 when our late President Kennedy included in our national policy a requirement to maintain a conventional war capability to counter aggression anywhere in the world. This portion of our national policy was reaffirmed by President Johnson in 1965 in his report to Congress.

On 25 March 1965 the Secretary of the Air Force stated - and I quote - "That since 1961 a great deal of effort has been given to building our limited war capabilities, and that this capability during the next 20 years will eventually increase to the point where it may become an effective deterrent to what might be classified as limited wars of less magnitude than Korea or perhaps Vietnam" - unquote.

Gentlemen, from this it is quite obvious our guidance is clear - to maintain an effective force we must keep our powder dry, so to speak; and, at the same time, prevent accidents to preserve operational resources.

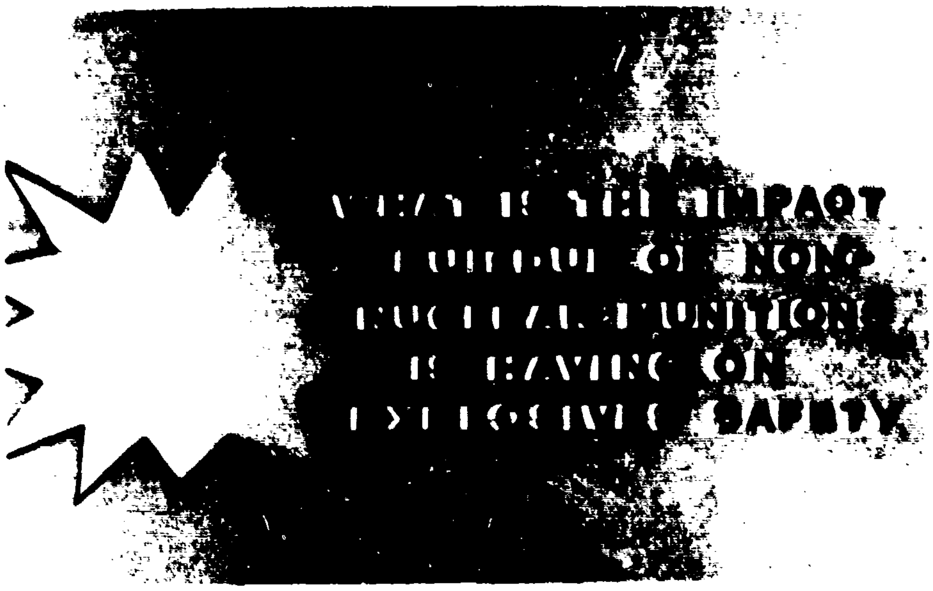


Figure 6

What is the impact on explosives safety?

As could be expected, our munitions buy program has been phenomenal. As can be seen on this next slide.

Figure 7

You will note the buy program was 1.2 million in 1964, but through 1967 it has peaked out at 3.1 billion. The 1968 figure of 2.2 billion was an earlier estimate and subject to modification at the close of our books at the end of the fiscal year.

As could be expected, this buy program has had a direct effect on industry and related support activities which many of you represent. To illustrate - 60% of these dollars are Army-produced or -procured items, 20% Navy, and 20% Air Force.

Figure 8

You might ask, how does my company or military service influence the Air Force Explosives Safety Program? In some cases newly developed munitions items have been marginal from the safety standpoint and incompatible with mission objectives. We have found safety devices missing or malassembled when we inspect the item. Other items have not proved entirely safe in the combat environment to which they were subjected, such as failure during flight or delivery. Some of these are:

(1) Premature functioning of bomb fuzes.
(2) Links jamming aircraft cannons.
(3) Premature functioning of flares.
(4) Malfunction of the retardation bomb fins.
(5) Hangfires in the minigun.

In fact, we have some instances of blowing holes in our own aircraft. Needless to say, this is a little alarming to our pilots, and jeopardizes multimillion-dollar aircraft and could degrade our capability to support Army and Marine ground forces such as the next Khe Sanh or Hue.

These problems, as they arise, require continued monitoring by the user and safety personnel to insure that remedial actions are expeditiously taken and that safety standards are developed to minimize these hazards.

In the area of hardware malfunction, i.e., equipment, aircraft, bomb/rocket/gunnery systems failures, we are pressing for improved engineering design and increased attention to the matter of "idiot-proofing" our conventional munitions systems.

This is the area where your company or military services can help us. For example:

(1) Will the end item produced maintain its safety integrity throughout the logistics pipeline and flight envelope with associated forces and temperatures and vibrations?

(2) Are production procedures compromising designed safety features?

(3) Are specifications being complied with?

(4) Are test procedures realistic, adequate, and are they being followed?

(5) Is the item designed and packaged to withstand shipment to and storage at forward areas such as tropic, subtropic, or arctic?

Any adverse effect on these inherently hazardous items introduced during any phase of their development, logistics, and storage can culminate in a catastrophic explosives accident on our airfields or during tactical delivery, resulting in multiple fatalities and/or loss of essential operational aircraft.

To illustrate, this next series of slides portrays what can and has happened.

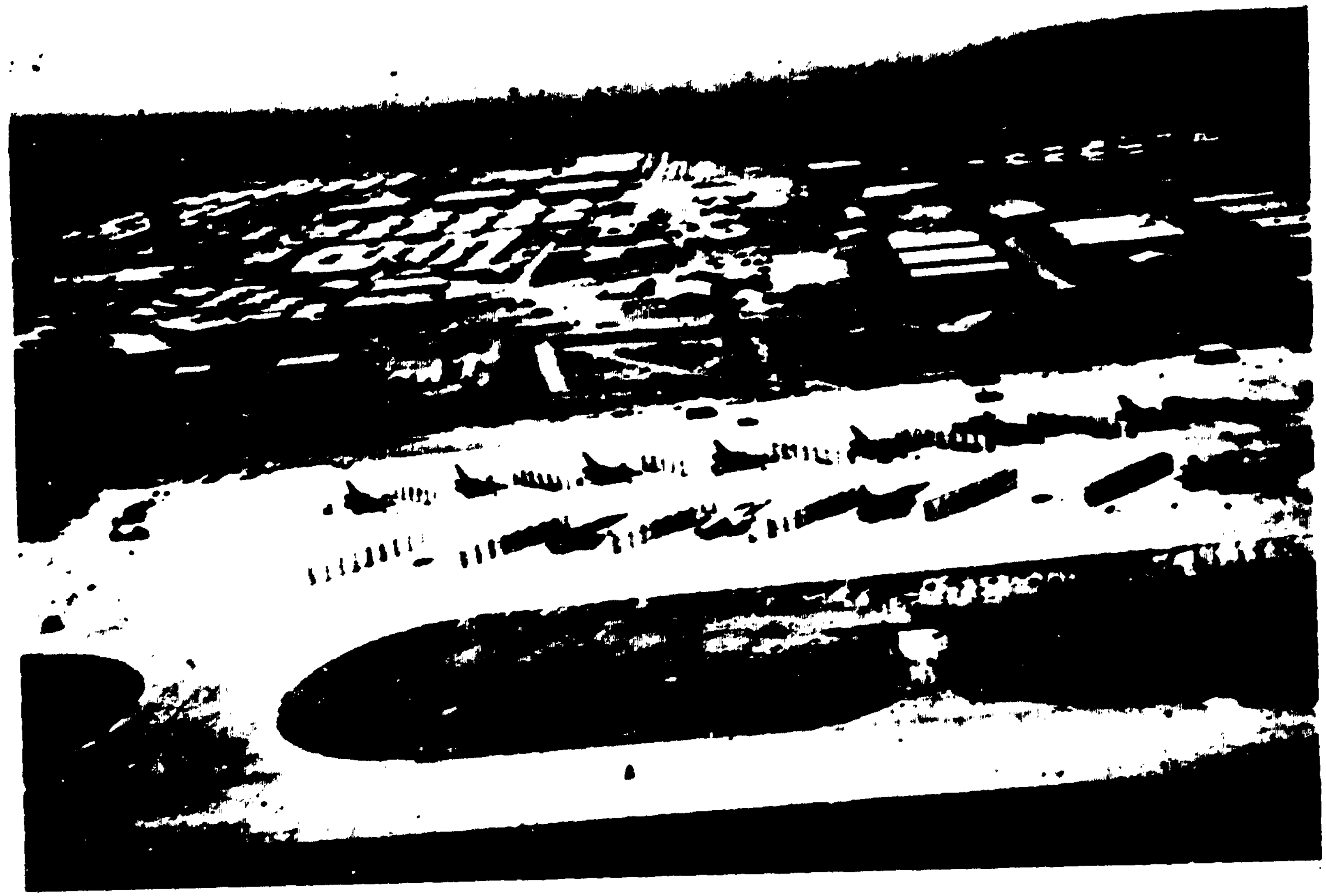


Figure 9

This first photo shows the congested flight-line condition we are forced to live with. The long, rectangular box-type structures you see are barricades to assist in preventing propagating explosions from aircraft to aircraft.

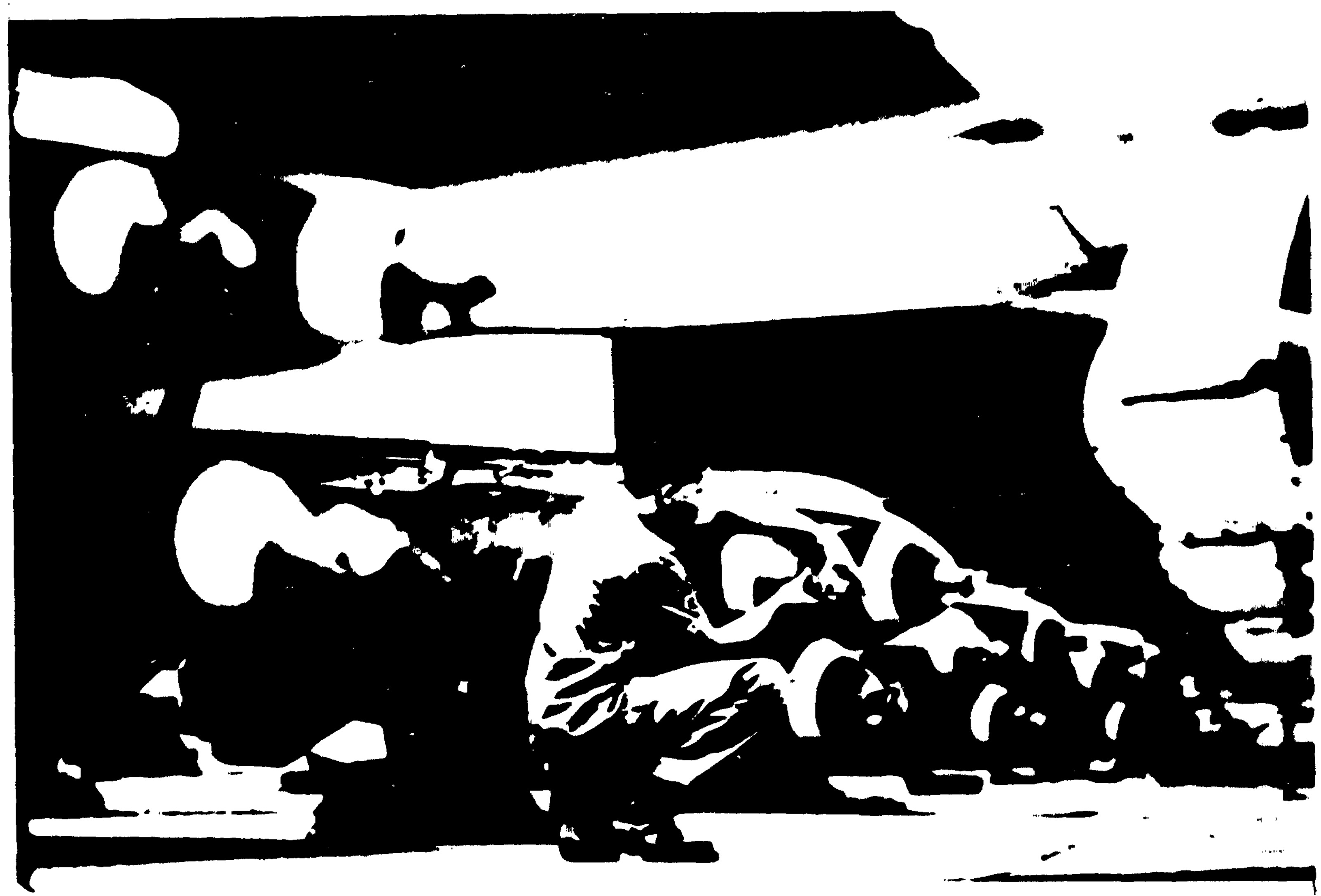


Figure 10

This shot shows an aircraft loaded with bombs.

Figure 11

This slide and the next are photos taken immediately after a series of bomb explosions on the flight line. We had 27 fatalities and 78 injuries in this one. We also lost 12 aircraft. Unfortunately, at this base barricades had not been constructed between aircraft.

Figure 12

Figure 13

Now, moving out to the storage area. In a bomb-unpacking operation, 3 were killed and 13 injured when 2 bombs detonated low order. The ensuing fires and explosion did most of the damage you see. Approximately 60,000 pounds of explosives (155 bombs) contributed to the degree of destruction you see in this storage revetment.

Figure 14

In this second event in the storage area we experienced three fatalities and six injuries. This was also an unpacking operation involving the unbanding and removal of the shipping pallet. There was a total of 81 bombs or 31,000 lbs. of explosives consumed in the series of fires and detonations.

Figure 15

Last Wednesday we had another accident similar to the ones I've just covered. We fortunately only had three injuries. A special investigation by Army and Air Force is currently under way to assist in determining why these bombs detonated.

Figure 16

Regardless of where these events occur, the price is too high in human lives and operational resources.

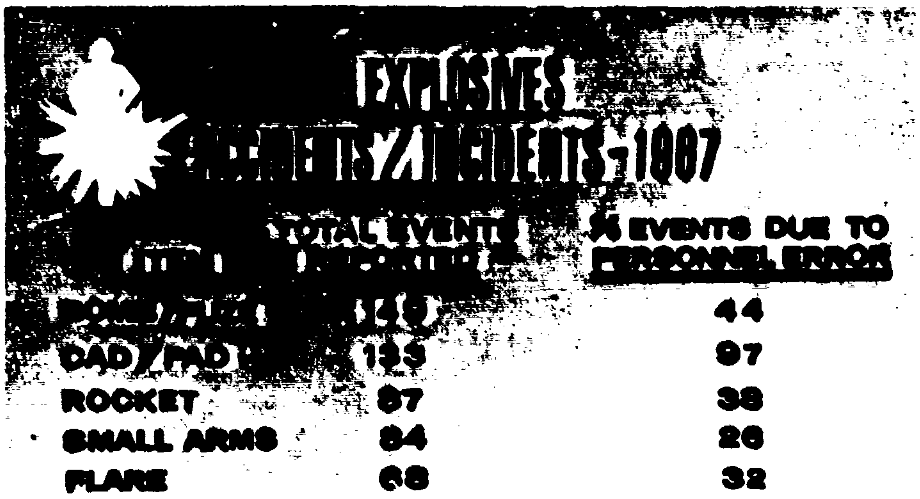


Figure 17

Now let's take a look at the statistical data and the cause factor areas. Analysis of 1967 explosives accident experience (521) showed that these items were high producers of explosives mishaps. They all are common of the flight line. Also, it should be quite obvious to many of you that we have a mutual safety interest and responsibility in the various phases of design, development, production, storage, and transportation of these items.

EXPLOSIVES ACCIDENTS / INCIDENTS

1ST & 2ND QTR CY1968

ITEM	TOTAL EVENTS REPORTED	% EVENTS DUE TO PERSONNEL ERROR
BOMB/FUZE	126	32
CAD/PAD	66	88
ROCKET	27	48
SMALL ARMS	58	29
FLARE/SIGNAL	17	41

Figure 18

As a matter of fact, current experience shows that these items still "lead the pack," with a slight reduction in the number of events for the first half of CY 1968.

EXPLOSIVES ACCIDENT CAUSE FACTORS

Figure 19

Now, in analyzing this experience you can see that hardware malfunctions and personnel error account for practically all documented explosives mishaps.

EXPLOSIVES • ACCIDENT PREVENTION MEASURES

- EXPLOSIVES SAFETY CONSIDERATIONS • PLANNING
- EXPLOSIVES SAFETY TRAINING
- EXPLOSIVES SAFETY SURVEYS
- DESIGNATION OF EXPLOSIVES OPERATING AREAS
- ELIMINATION OF UNSUITABLE PERSONNEL
- CERTIFICATION OF MUNITIONS PERSONNEL
- USE ONLY OPERATIONALLY READY ACFT
- INSURE AVAILABILITY OF PROPER TOOLS & EQUIPMENT
- INSURE AVAILABILITY OF CHECK LISTS & SOPs
- INSURE ADHERENCE TO TECH DATA
- INSURE ADEQUATE EXPLOSIVES STORAGE

Figure 20

To take care of our side of the problem, personnel error, this slide (Figure 20) reflects some of the special-interest items and areas where we have intensified our safety efforts. For instance:

(1) In coordination with our training people we have developed an advanced explosives safety officer course which will consist of eighteen weeks of intensified specialized training. This course starts the first of the year 1969 at Lowry AFB, Colorado.

(2) We have and are continuing to increase the scope and depth of our safety surveys of selected units who appear to be having problems.

(3) We completed a series of explosives tests known as "Big Papa." These tests validated the five-cell module "desk study" concept which we had been using in SEA since 1966. The data from these tests clearly demonstrated that the module could be increased to eight cells, each holding 250,000 pounds of explosives. Twenty four of these cells can be placed in the same land area required for six under DOD criteria. These new Air Force criteria are being used in the Far East and Europe under the Chief of Staff-approved exemption to DOD standards.

(4) The chemical-biological chapter of our Explosives Safety Manual has been revised and updated.

(5) Numerous projects, campaigns, and special-subject letters have been initiated to enhance explosives safety discipline and supervision.

If we are to reduce the number of explosives accidents occurring in the USAF, we must exert greater effort toward diminishing the number of mishaps.

How can we accomplish this?

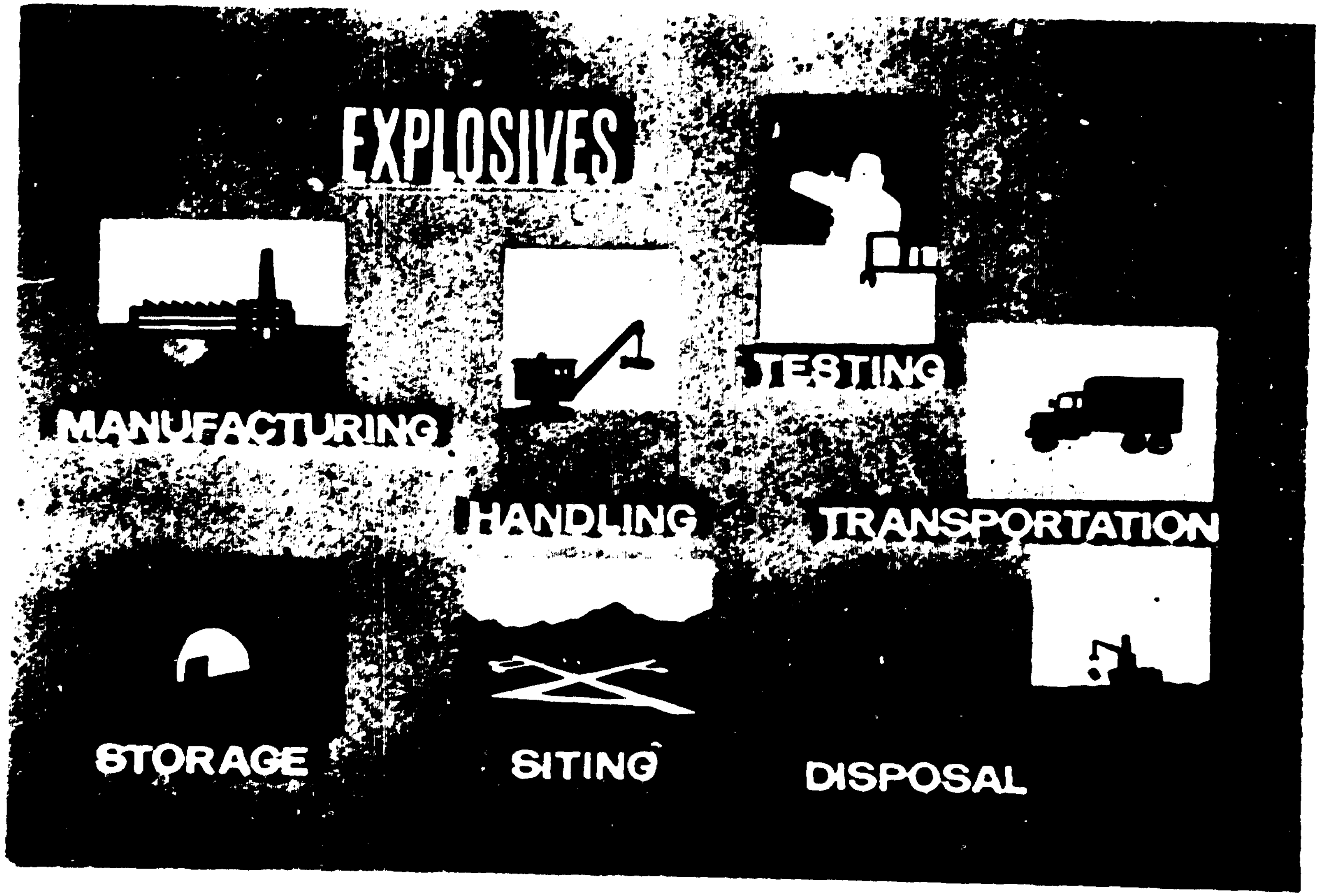


Figure 21

Program effectiveness does not begin when explosives are delivered to the flight line - it starts on _your_ design table and continues throughout _your_ development of _your_ production, _your_ testing, _your_ transportation, _your_ storage, our handling, and our delivery to the target.

EXPLOSIVES ACCIDENT CAUSE FACTORS

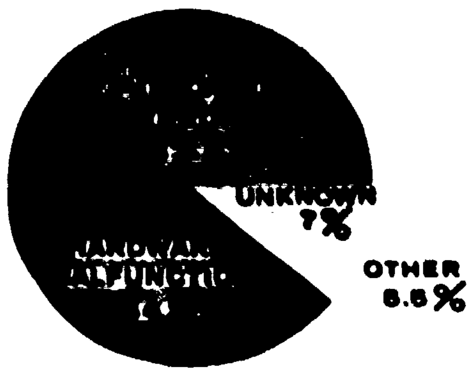


Figure 22

Therefore, we in the Air Force solicit your assistance in reducing the 44% material failure and malfunctions accident data to assure that the items you are involved with maintain their safety integrity throughout the life cycle in the interest of supporting our national policy.

Figure 23

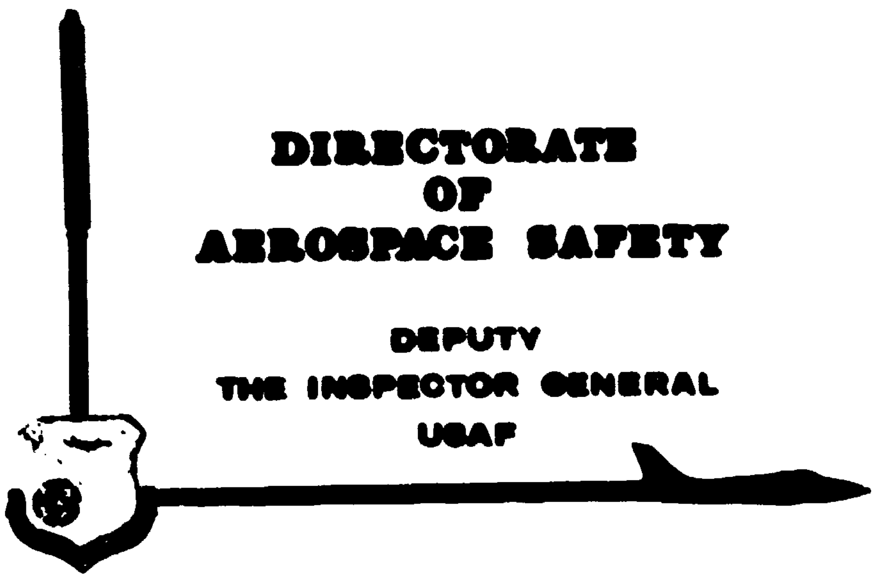


Figure 24

THE US ARMY CB WEAPONS SURETY PROGRAM

by

John L. Chamberlin
Special Assistant to the Commanding General
for Nuclear, Chemical and Biological Affairs,
Army Materiel Command

This paper is "FOR OFFICIAL USE ONLY" and is

contained in Volume II.

HIGH EXPLOSIVES AND DASA

by

Jack R. Kelso
Defense Atomic Support Agency
Washington, D. C.

Background

The mission of the Defense Atomic Support Agency is to provide support to the Secretary of Defense, the Joint Chiefs of Staff, the Military Departments and other DOD agencies as may be appropriate in matters concerned with nuclear weapons effects tests and other aspects of the DOD nuclear energy program as may be directed by the Secretary of Defense. This present day organization had as its beginning the Manhattan Project of the 1940's and the Armed Forces Special Weapons Project of the 1950's. Within its basic charter, the DASA supports an active research and test effort that encompasses the entire spectrum of nuclear weapons effects.

High Explosive Field Testing

One of the functions of the DASA is to develop nuclear weapons effects data, to evaluate this data, and to disseminate the results of such evaluations appropriately. Before prohibition of atmospheric nuclear testing, a major portion of the DASA's effort was expended in conducting and evaluating nuclear tests. Nuclear weapons effects data has been published by the DASA in both classified and unclassified form since the late 1940's. These effects data have been continually updated as accuracies have been improved or techniques have been refined.

Since 1958, the DASA has sponsored broad development of economic simulation techniques for the study of all nuclear weapons effects. These simulation techniques have been pursued because, in addition to the expense of nuclear tests, the data from such tests have inherent inaccuracies and are not usually reproducible. Further the complexity of nuclear tests adds to the expense and creates bothersome delays. Simulation techniques for the studies of blast effects have produced quite worthwhile results. Carefully developed scaling laws are valid throughout large distances and varying charge weights. Shock tubes, as well as a variety of blast load generators, have been used successfully. Since 1959, the DASA has participated in multi-ton TNT field experiments in Canada. This participation has been primarily under the auspices of The Technical Cooperation Program (TTCP), a quadripartite agreement among the United States, United Kingdom, Canada and Australia, for the development and sharing of information. Beginning in 1959 with a 5-ton

Canadian TNT test, U.S. participation in large scale high explosive field tests has continued through 20-, and 100-, and 500-ton TTCP experiments in 1960, 1961 and 1964 - as well as the multi-event Operation DISTANT PLAIN, conducted in Canada from July 1966 through August 1967. The most recent test was Operation PRAIRIE FLAT, conducted on 8 August 1968. All of these large-scale TNT experiments partially satisfy the continuing requirements for obtaining data on blast and shock phenomena, to obtain target response information, to develop new simulation techniques, and for a combination of these reasons.

Operation DISTANT PLAIN

Operation DISTANT PLAIN was a series of large scale TNT experiments conducted in Canada in July 1966 through August 1967 under TTCP auspices. The event dates and charge characteristics were:

Shot No.	Date	Type	Shape	Height (Center)
1	12 July 1966	20-Ton/TNT	Spherical	85.9 Feet
2a	22 July 1966	Propane-Oxygen (20-ton TNT yield)	Hemispherical	0
3	28 July 1966	20-ton/TNT	Spherical	0
4	16 Aug 1966	50-ton/TNT	Hemispherical	0
5	9 Feb 1967	20-ton/TNT	Spherical	0
6a	18 May 1967	20-ton/TNT	Spherical	Tangent
6	26 July 1967	100-ton/TNT	Spherical	Tangent
1a	18 Aug 1967	20-ton/TNT	Sphere	28 Feet

Event 1 was conducted primarily for the purpose of recording fundamental data on air blast, the flow phenomena in the mach and regular reflection regions, and the air-induced ground shock from this tower shot. A second goal was to analyze and correlate these measurements with theoretical predictions made from newly developed one- and two-dimensional computer codes. Results - A high order detonation was achieved. Non-classical wave shapes were recorded at certain close-in air blast stations. There was an unexpected amount of steel fragments ejected from the tower platform causing damage to gages, cable and gage mounts.

Event 2a was conducted to explore the feasibility of applying the detonable gas simulation techniques to large yields for further target response studies. Secondary objectives were to compare the measured blast parameters with 20 ton hemispherical charges fired previously and to validate applicable theoretical predictions. Results - A high order detonation was achieved. Measured overpressures and arrival time vs distance agreed well with predictions. Demonstrated that stable detonation waves can be achieved in large volume gas mixtures. There was no crater hence no crater ejecta.

Event 3 was an additional basic data experiment that was conducted to gather more fundamental data on close-in ground shock phenomena and for the purpose of correlating results with 20-ton spherical shots at the Nevada Test Site in 1964. Results - much good data was recorded, analyses not yet complete.

Event 4, the locale shifted to the forest near Hinton, Alberta, Canada. Event 4, also called BLOWDOWN II, had two main objectives. The first of these was to develop experimental data concerning the effects of air blast and ground shock on trees in a coniferous forest and the corresponding effect of the forest on the attenuation of air blast and air-induced ground shock within the forest. The secondary main objective was to study the practical military aspects of tree blowdown on troops and material within the forest and of post-shot troop and vehicular movement capabilities. Results - the forest appears to have had some effect in attenuating the passage of the blast wave and ground shock thru it. Much good data was recorded.

Event 5 was conducted in a frozen environment. The primary objective of this event was to determine the effects of a frozen ground surface on cratering, ground shock, and air blast propagation. A second objective was to determine the effects of a ground snow cover on air blast propagation over ground surface and into snow tunnels. Results - good data recorded.

Event 6a, a prelude to Event 6, was conducted to document the expected air blast and to determine the size and shape of the crater that might be expected from a larger spherical charge placed tangent to the ground surface.

Event 6 was primarily conducted to obtain experimental data on direct and air-induced ground motion. Additional air blast data was obtained for comparison with the results of newly-produced theoretical predictions. Finally, crater aspect ratios were documented to determine correlation with crater data already obtained from nuclear detonations of an equivalent yield.

Event 1a, the last event of the Operation DISTANT PLAIN SERIES, was conducted to develop experimental data on air blast and air-induced ground motion in overpressure regions from 300 to 10,000 psi.

Operation DISTANT PLAIN was successful. This particular simulation technique proved to be reliable, economical, and useful. Because of the success of Operation DISTANT PLAIN, the DASA decided to proceed with Operation PRAIRIE FLAT, a 500-ton TNT experiment in the DRES on 8 August 1968.

Operation PRAIRIE FLAT

Operation PRAIRIE FLAT was the nickname given to U.S. participation in a single 500-ton TNT blast and shock experiment conducted on 8 August 1968 at the Canadian Defence Research Establishment, Suffield (DRES), under the auspices of the TTCP. The test was designed to provide experimental data required for the solution of nuclear weapons effects problems based upon specific military requirements and was the culmination of test planning coordinated by Panel N-2 (Blast & Shock) of the TTCP. The primary objective of Operation PRAIRIE FLAT was to obtain loading and response data for a variety of military targets, e.g., missiles, communications, and other field equipment, shelters, and various structural components. The secondary objective was to obtain experimental data on air blast and ground motion, both direct and air-blast induced, beyond that required to define target loading.

Operation PRAIRIE FLAT was a logical extension of efforts expended during the DISTANT PLAIN series and provided important scaling relationships. In DISTANT PLAIN events 62 (20-ton) and 6 (100-ton), and in Operation PRAIRIE FLAT (500-ton), a spherical charge tangential to the earth was detonated. This similarity plus the sameness of geological medium will permit evaluation of yield effects over a 25-fold yield range.

In addition to the direct application of target response data to specifically exposed targets, the basic phenomenology and response results will be used to verify and improve our existing calculation techniques for predicting blast and shock effects.

As a result of blast research and testing, the environment produced by the blast and shock fraction of a nuclear yield is relatively well defined. The significant parameters of the blast environment have been identified; they are arrival time, overpressure, overpressure impulse, dynamic pressure, dynamic pressure impulse, and positive pulse duration. The response of military weapons systems, personnel, equipment, and installations to this environment is essential nuclear weapons effects information. This information is continually being expanded and refined as a result of high explosives tests. The need to also refine and expand the data base for explosives safety criteria for storage and transportation has long been recognized by DASA, which is very much involved in developing safety criteria for the storage and transport of nuclear weapons. Pursuit of solutions to safety problems occurs in different modes. One mode is to designate one of the projects in a high explosive test program as a safety project. For example, Project LN104 of Operation PRAIRIE FLAT is to study the blast effects on a residential dwelling. The objectives of this project are to obtain data which will permit improvement in predictions of damage to residential type structures exposed to the blast from large high explosive detonations and to correlate the data with predictions based on smaller blasts. The results

of this and similar efforts could well bring about a change in the current quantity-distance criteria for inhabited buildings. Another mode is the design and execution of field experiments devoted solely to the generation of data for safety purposes. The series of igloo tests conducted at Hastings, Nebraska in 1964 was such a test series. The problem addressed there was weapon-to-weapon propagation through a dividing wall. Still another mode is that of conducting analyses of field test data and development of theory to explain what has occurred and to predict what may occur under slightly different circumstances. In 1966 a DASA contractor analyzed the Hastings tests, developed theory to explain the phenomena, identified the significant parameters, and recommended further tests and studies. Early this year a contractor was engaged to pursue one of these recommendations - that of developing a scheme of categorizing weapons as to sensitivity of their high explosive contents to detonation in an accident scenario.

Conclusion

Thus DASA's search for useful and economic blast simulation techniques has found that high explosive field tests do provide a means for creating a blast environment which suitably simulates that of a nuclear detonation. These tests have contributed greatly to the field of blast phenomenology and to the technology of predicting the response of various targets to a blast environment. The data generated, the instrumentation developed, and the people who have contributed to the planning and execution of high explosive field tests are of great value to the nuclear weapons effect effort. These resources and assets have in the past also been put to beneficial use for explosives safety purposes and it shall be so in the future.

PROTECTIVE CONSTRUCTION FOR

EXPLOSIVES FACILITIES

Moderator: George F. Wigger
Office, Chief of Engineers
Department of the Army
Washington, D. C.

APPLICATION OF NEW DESIGN TECHNIQUES FOR HIGH CAPACITY PROTECTIVE BARRIERS - CASE STUDIES

by

Edward Cohen and Norval Dobbs
Ammann & Whitney, Consulting Engineers
New York, New York

ABSTRACT

Recent tests of blast resistant structures have demonstrated that, when properly designed and detailed, reinforced concrete and other materials may be used effectively to prevent propagation of explosions and to provide protection from injury for personnel and vulnerable equipment. Results of these tests have lead to the development of design criteria which recently have been utilized in the design of several new explosives manufacturing and/or storage faciltiies.

This paper describes the philosophy and procedures used inthe siting and design of the above facilities. Included is a discussion of methods used for providing protection for personnel and equipment close-in to and/or at larger distances from an explosion. Here, the sizes of various structural elements, construction costs and structure motions including deflections, velocities and accelerations are described. Also discussed are methods used to prevent propagation of explosion between cells in addition to methods used to protect buildings located close-to a potential explosive hazardous area.

APPLICATION OF NEW DESIGN TECHNIQUES FOR HIGH CAPACITY PROTECTIVE BARRIERS - CASE STUDIES

INTRODUCTION

For the last half-century, military and commerical explosive facilities have been designed utilizing criteria and methods based upon results of catastrophic events. So called safe distances were established for separation of explosive materials from other explosives, personnel, roads, etc. In many cases these separation distances were far in excess of that which can be tolerated in modern, economically efficient explosive storage and/or manufacturing facilities. Furthermore, these criteria and method did not include a reliable quantitive basis for assessing in detail the degree of protection afforded by the protective facilities.

Therefore, extensive research and development programs are underway to establish procedures which are adequate for current and future design requirements. Procedures, which have already evolved from these programs, are contained in the proposed "Manual for Design of Protective Structures Used in Explosive Processing and Storage Facilities", which is currently under review. During the preparation of this manual, certain case studies were reviewed to "test" the application of the new design techniques. These studies which included both preliminary and final designs as well as concept studies of future explosive facilities are contained in the paper.

The data reported here was developed by Ammann & Whitney under Contract DAAA-21-67-0217 and 0941 to Picatinny Arsenal as part of their supporting studies program of the Armed Services Explosives Safety Board and other related projects.

CASE I - FINAL ASSEMBLY AND TEST FACILITY

The Final Assembly and Test Facility consists of three structures, namely: (1) Assembly Building, (2) Control Room and (3) Test Cells (Fig. 1). The purpose of this facility is for the final assembly and testing of Walleye Missiles presently being manufactured by Hughes Aircraft Co. at the U.S. Air Force Plant 44, Tucson, Arizona. Assembly of the missile is accomplished in the Assembly Building while testing is performed in the Test Cells. The Control Room contains recording and control equipment and personnel required to perform the tests.

The operation of the facility consists of transporting missile parts by truck to the Assembly Building where the individual missiles are assembled. Upon completion of the assembly process, the missiles are transported by buggy through a covered access corridor to the Test Cells. After testing the missiles are then returned to the Assembly Building and placed on trucks for shipment. The facility is in continuous operation requiring approximately 15 and 20 minutes for the assembly and testing of each missile, respectively. The hazardous part of the operation occurs during the test phase at which time a potential explosion of 1200 pounds of H.E. (TNT bare charge equivalent) in one of the test cells has been assumed in the facility design.

Siting

All structures of the Final Assembly and Test Facility are separated from other buildings of the manufacturing complex by Intraline Distances and by Inhabited Building Distances from off-site facilities. On the other hand separations between the individual structures of the Facility are not a function of safety distances. Here the distances between the structures have been computed based upon the capabilities of the individual structures to resist the output of the previously mentioned potential explosion, the protection requirements of the building contents and operational requirements.

A one-story reinforced concrete flat-slab building is utilized for the Assembly Building. This structure is essentially located above grade while the Control Room which is also a box type reinforced concrete building is located such that its roof is flush with the ground surface. The test cell structure

consists of two intersecting concrete walls formed in the shape of a tee. The top of the tee faces the Assembly Building while the wall forming the stem separates the two cells. The Control Room is located between the other two buildings (Fig. 1).

The present volume of work requires the doors at the shipping and receiving dock located at the rear (side of building opposite to that facing the Test Cells) of the Assembly Building to be opened the major portion of the time. Therefore, to provide a reasonable degree of protection for personnel working in the building and on the dock, the structure is located at a distance further away from the potential explosion than would be required by Intraline Distances. The surface of the structure facing the Test Cells is 364 ft. from the potential explosion. At this distance the Side-on P_{so} and face-on P_r pressures are 1.5 and 3.0 psi, respectively, while in the vicinity of the loading dock the side-on pressure is approximately 1.1 psi. Because of this reduced pressure, personnel located near the open end of the structure would be less susceptible to injury then personnel at similar structures located at Intraline Distances (approximately 3.4 psi for this facility). The main danger to personnel at the 1.1 psi level is the possibility of being knocked over or struck by flying debris.

The length of the electrical connection between the control panel and the test stand is a critical item in the testing operation. This critical dimension is the predetermining factor which was used for the selection of the 31 ft. separation distance between the center of the roof of the Control Room and the test stand. This distance corresponds to a peak side-on pressure of approximately 140 psi on the Control Room roof.

In the initial phase of the design study, consideration was given to locating the Control Room above ground. Although it was found that the structure could be designed to resist overturning due to the face-on pressures associated with the above side-on load, the increased thicknesses of the walls and side of the foundation (monolithic floor slab) above those required for the below ground structure rendered the above ground configuration uneconomical. Also added protection against debris from the Test Cells would be provided with the below ground arrangement.

Because the fragment impact sensitivity of the missiles is unkonwn at this time, the blast walls of the Test Cells were designed for incipient failure conditions. As will be explained later, if future sensitivity tests indicate that failure of the structure with residual fragment velocities may be tolerated,

upgrading of the facility for a larger explosive equivalent may be achieved.

Test Cell Structure

The test cell structure consists of two adjacent cells, each 25 ft. long by 18 ft. wide by 12 ft. high (Fig. 2). Each cell is separated from the other by a 3 ft.-6 in. thick laced reinforced concrete wall (hereafter referred to as the side wall). The exterior wall of each cell (hereafter referred to as back walls) facing the other structures of the facility are of similar construction as that of the side wall. The remaining walls and roof of each cell are constructed of light metal siding and decking, respectively.

As previously mentioned, both reinforced concrete walls have been designed to resist, without failure, the blast output from 1200 pounds of H.E. located at the center of the cell (walls designed for incipient failure conditions). A safety factor of 25 percent on the weight of the explosive was used in the design (actual charge weight used in the calculations was 1500 pounds of H.E.).

The side and back walls are supported in similar fashion, namely: (1) at the floor slab and (2) by each other at their intersection. The flexural reinforcement, approximately 0.25 percent in each direction on each face, is continuous in any one direction and tied by bent diagonal bars or lacing which fully develop the ultimate capacity of the flexural reinforcement including the strain hardening region. To fully develop the moment capacities of the concrete sections at the supports, the floor slab and side wall were extended beyond the back wall. This extension not only provided the required anchorage for the floor and side wall reinforcement but also resists overturning caused by the unbalanced blast loads acting on the back wall.

Although the structure was designed for incipient failure conditions as a result of a detonation of 1200 pounds of H.E., the explosive capacity of the test cells may be upgraded if it is determined that the acceptor explosive can withstand, without detonating, the impact of concrete fragments resulting from the collapse of the structure. This upgrading would require sensitivity tests of the explosive to be contained in the structure. These tests would consist of a series of impact tests where concrete fragments of known velocity would be propelled against the missile. For the following fragment velocities the explosive capacity of the structure may be upgraded to:

Fragment Velocity (fps)	Explosive Weight (lbs. of TNT)
100	1800
200	3000
300	4500

In addition to their ability to resist the blast output, the back and side walls were evaluated to determine their capability to resist penetration of primary missiles. It was determined that the 3 ft.-6 in. thickness required for the blast overpressures would also prevent full penetration of a 30 ounce armor-piercing steel fragment having an impact velocity of 6000 fps (Ref. 1).

Control Room

The Control Room (Fig. 3) is a reinforced concrete box-shaped structure located adjacent to the back wall of the test cell structure. The interior dimensions are 15 ft. long by 15 ft. wide by 10 ft. high. The structure is buried (top of roof slab located at the ground surface) to resist overturning due to the unbalanced blast loads which could occur if the structure was located above ground and to minimize the blast loads acting on the walls of the structure as a result of the blast wave propagation over and around the back wall of the Test Cells.

The roof and floor slabs are 10 and 12 inches thick, respectively, whereas all four walls of the structure are 1 ft.-3 in. thick. The roof, floor slab and walls are reinforced with approximately 0.25 percent reinforcement each way on each face.

Entrance to the structure is by means of a stairway. This entrance, which is protected by a blast door, is located on the side of the structure facing away from the test cells. The door is designed to resist both the positive and negative phase pressures of the blast in addition to elastic rebound. Because the door is not subjected to the close-in effects of the detonation (high-intensity non-uniform pressures), a channel beam and steel cover plate structural system could be used for the door design (Fig. 4). Dislodgement of the door, due to negative pressures and/or elastic rebound, is prevented by a rebound

system consisting of strengthened hinges on one side of the door and a door release mechanism at the other side. Under the action of the positive pressures, the door will essentially span in the horizontal direction which provides the greatest strength for the door. On the other hand, the negative pressures and rebound are resisted by the vertical spanning of the door. For short duration loads, the strength of an element required to resist the elastic rebound is almost as large as that required to resist the positive loads if the system is to remain elastic during the reversal phase. For the case at hand, the vertical channels provide the main support for the other elements of the door and therefore form a weaker system than the door's response to the positive pressures. These channels will yield as a result of the rebound and thereby produce a door resistance to the negative loads less than its positive resistance. This reduced negative strength will in turn require weaker hinges and release mechanism than would be necessary if the door remained elastic during reversal.

Also located at the same side of the structure as the blast doors are two 10-inch by 14-inch openings - one each for the air supply and exhaust systems (Fig. 3). At the exterior of the structure the air supply opening is connected by a metal duct to a portable heater-air-conditioning unit located on the roof while closure for the exhaust opening is provided by a standard metal weather hood. Both the duct to the air intake and the exhaust hood will fail as a result of the blast. However, both openings are protected with steel gratings to prevent large debris from entering the structure. The build-up in the interior pressure due to the blast passage through the opening is approximately 2 psi which is far below the pressure tolerance of man (Ref. 1 and 2). By locating the openings just below the roof slab, protection against the jetting effects produced by the confinement of the blast as it passes through the openings is provided for the personnel and equipment within the structure.

Although the damage to the Control Room will be relatively small, the degree of damage may be such to render the building useless after an explosion of 1200 pounds of H.E. in the test cells. The building would fail as a result of a 4500 pound explosion (post-failure fragment velocity of 300 fps). Therefore, if the charge capacity of the testing structure was upgraded, a new Control Room would be required. The new structure probably could be designed for the same location as the present building.

Assembly Building

The Assembly Building (Fig. 5) is a reinforced concrete

structure having exterior plan dimensions of 60 ft.-0 in. long and 60 ft.-0 in. wide. The clear interior height varies from 12 ft.-0 in. at the wall facing the test cells to 13 ft.-3 in. at the opposite side. The roof is a 10 in. thick reinforced concrete flat slab supported at the periphery by reinforced concrete monolithic walls and at the center by one 1 ft. diameter reinforced concrete column. The floor is a 6 in. thick reinforced concrete slab on grade.

Door openings are located in all four walls of the building. The wall facing the potential hazard has one 5 ft. wide by 7 ft. high steel blast door which is interlocked with the missile testing operation. The design of this door is similar to that described for the door of the Control Room. This door gives access to the corridor connecting to the Test Cells through which the assembled missiles are taken to the test stands. The opposite wall has three openings; two large openings, 10 ft. wide by 10 ft. high, used for shipping and receiving and a third opening located at the center for the passage of personnel. Doors for the above openings are conventional doors. The remaining two side walls each have a 5 ft. wide by 7 ft. high opening centrally located where conventional doors are again used. Pilasters for future blast doors have been provided for all these openings if future upgrading of the structure is required.

The Assembly Building, which was also designed for conventional live and dead loads using working stresses, is located 364 ft. from the test stand containing the explosive. For an explosion of 1200 pounds of TNT in one of the test cells, the blast overpressure acting on the ground at the structure would be approximately equal to 1.5 psi. This blast load would result in minor damage to the building (all elements of the structure will remain elastic). However, if an explosion of 4500 pounds of TNT (fragment velocity of 300 fps) should occur, then the side-on pressure would be approximately 3 psi. Although the damage to the structure would be significantly greater at this larger pressure level, the structure would still be usable.

The maximum capacity of the structure is approximately 4.5 psi which would be produced by an explosion of 13,500 pounds in the test cells. Although the roof slab would not collapse, the damage resulting from an explosion of this magnitude would be so severe that the structure would not be usable. It should be noted that the Assembly Building would survive the blast output of 4500 pounds of explosive and, therefore, could be used as an integral part of an upgraded facility. However, some modifications would be required, such as blast doors to seal the openings where conventional doors are presently being used.

CASE II - PROPOSED PRODUCTION FACILITY
CLASS 7 PROPELLANT ROCKET MOTOR

With the development of larger rocket motors containing Class 7-propellant, new production facilities must be designed to prevent mass detonation in the event of an accidental initiation in a single unit and to provide protection for operating and other personnel. This section of this paper describes such a facility and in particular the results of a design concept study of new protective structures to house several of the operations required for the manufacture of a multi-stage rocket motor containing Class 7 propellant.

The proposed facility will consist of two buildings housing the curing operation of the propellant while a third structure will be used for X-raying the propellant grain after the curing phase has been completed. The buildings for the curing operation will not necessarily be located near the X-ray structure and therefore the siting of the curing operation buildings will be independent of the site location of the X-ray building. However, all three structures are separated from other buildings of the facility by Intraline Distances and from off-site areas by Inhabited Distance regulations.

Curing Facility

Each building used for the curing operation is long and rectangular in shape and one story in height. The larger of the two structures (Building No. 1) is used for curing of the first stage propellant while curing of the propellant for the second stage is performed in Building No. 2 (smaller building). The usable floor area is 2200 and 1100 square feet for Building No. 1 and No. 2, respectively.

Basically, each structure is separated into two sections by a longitudinal dividing wall (hereafter referred to as the back wall). Each side of the structure is further subdivided into smaller areas by transverse or side walls. The intersection of the central or back wall and the side walls form compartments or cubicles. All cubicles have the same interior dimensions, i.e., 12 ft. wide by 11 ft. deep by 18 ft. high. Building No. 1 has a total of 22 cells; one-half of which is located at each side of the back wall. The smaller structure has a total of 11 cells (6 and 5 cells at each side of the back wall, respectively).

To achieve economy in the design, each side wall at one side of the back wall of each structure is so located that an extension of the wall past the back wall would bisect the cell at

the opposite side of the building. This arrangement results in a shorter unsupported length of the back wall than would otherwise occur if the side walls were continuous across the building. Both the back and side walls and the floor slab of each cell of both structures are reinforced concrete elements while the front wall (exterior wall) and the roof of each cell are constructed of insulated metal panels and lightweight steel joists with metal decking, respectively. The roof and front wall will fail as a result of an explosion in one of the cells thereby providing relief for the high pressures associated with the initial portion of the blast output as well as providing relief for the gaseous products of the explosion.

In addition to the structure proper, each building required a barricade adjacent to one of its long sides in order that the building could be sited based on Barricaded Inhabited Distances from off-site facilities.

Both buildings were designed to prevent propagation of explosion from one cell to another. However, because of the relative insensitivity of the propellant (as evaluated based on standard sensitivity tests) the criteria used for the design of both structures was based upon permitting the occurrence of post-failure fragments (partial failure of the structure) with limited velocities rather than incipient failure design conditions where the integrity of the structure must be maintained. Building No. 1 was designed for a potential explosion of 3750 pounds of H.E. located in any one cell while the design of Building No. 2 considered a potential explosion of either 2020 or 3750 pounds in a cubicle. Fragment velocities used in the design study were 100 and 200 fps.

Both the back and side walls of both structures are designed utilizing lacing reinforcement while the floor slabs are unlaced elements. Vertical and horizontal lacing is used in the side walls whereas because of the short span between side wall supports, horizontal lacing only is used in the back wall. The ratio of the vertical to horizontal reinforcement ($p_V/p_H = 2.12$) used in the side walls is an optimum value (for incipient failure conditions) which will give a maximum impulse capacity for a given total amount of flexural reinforcement (Ref. 1). Also the absolute values of the reinforcement percentages ($p_V = 0.62\%$ and $p_H = 0.29\%$) are only slightly higher than those steel percentages which in combination with the associated concrete thicknesses will achieve a minimum structural cost. Table 1 lists the various concrete thicknesses, for both the walls and floor slab, required to limit velocities of fragments produced by the previously mentioned explosive quantities to a tolerable level.

A comparison of the summary of the estimated structural construction costs (Table 2) for the individual buildings indicate that, regardless of the magnitude of the fragment velocities considered; the cost of the main structure of Building No. 1 which was designed for an explosive quantity of 3750 pounds is approximately 1.9 times that of Building No. 2. The latter structure has one-half the number of cubicles as the former building. If the costs of the barricades are included in the above comparison, then the cost differential between the two structures is reduced to 1.82. A further examination of Table 2 indicates that the upgrading of the design of Building No. 1 and No. 2 from a fragment velocity criteria of 200 fps to 100 fps will result in an increase estimated construction cost of approximately 35 percent for each structure. This latter increased cost is reduced to approximately 25 percent when the barricade construction cost is added to the cost of the main structure.

X-Ray Facility

The structure utilized for the X-ray operation is subdivided into three sections, i.e., (1) Storage Area, (2) X-Ray Room, and (3) the Shelter Area (Fig. 8). The first two sections are designed to prevent propagation of explosion from one area to the other. The maximum quantity of explosives contained in either (or in both) area is 4000 pounds of H.E. equivalent. The third section of the building is designed to provide protection for operating personnel from the effects of an explosion in one of the other two areas.

The operation of the facility consists of transporting the propellant grain to the X-Ray Room by vehcile from other on-site facilities or from the Storage Area where the propellant had been stored subsequent to previous deliveries. An access tunnel for the vehicle is provided to allow movement of grain to a point immediately adjacent to the open end (front end) of the X-Ray cubicle. An overhead crane is used to unload the truck and place the propellant into the required position in the X-Ray Room. A buggy is used to take the remaining grain from the truck to the Storage Area. The X-ray equipment is located on a second overhead crane which can travel the full length and width of the X-Ray Room Operation of the equipment is accomplished from the control room located in the Shelter adjacent to the wall separating the personnel area from the operating cubicle (X-Ray Room). Because the length of the electrical connection between the X-ray equipment and operator's panel is a critical factor in the performance of the test, the Shelter had to be located adjacent to the operation area and thereby eliminated the possibility of using separation distances to provide the required protection. Other areas in the Shelter include: (a) dark room, (b) view room, (c) office area, (d) toilet, (e) equipment area and (f) storage area. As will be shown later,

the location of these areas within the Shelter will vary depending upon the level of protection for the personnel desired.

Based upon the above operating procedures and the possibility of a variation of the protection level, two schemes have been developed for the personnel area. Also alternate designs for the cubicle areas of the structure have been investigated and include both incipient failure and limited fragment velocity criteria for the cubicle wall design. Fragment velocities were limited to 100 feet per second. A safety factor of 20 percent on the weight of the explosive was used in the following designs (actual weight used in the calculations was 4800 pounds).

a. X-Ray Room and Storage Area

The clear floor dimensions of the X-Ray Room are 30 feet wide by 20 feet deep while the width and depth of the Storage Area is 12 feet and 20 feet, respectively. Each area is enclosed on three sides by reinforced concrete walls. One wall which forms the exterior surface of the back of the building is common to both areas and is referred to as the back wall. The other two walls of each cell are side walls and are used to separate the individual areas from the adjoining portions of the building. All concrete walls of both areas are 26 feet high. However, the walls of the X-Ray Room are continued above the concrete portion of the building for an additional 9 feet. The section of the walls above the concrete are constructed of light metal siding and are used to enclose the area required for the overhead crane. The roof of both cubicle areas is constructed of light metal joists and decking. The metal walls and roofs are considered frangible in the event of an explosion.

The 6 foot thickness of the concrete walls enclosing the X-Ray Room is required for radiation protection. However, if the back wall and the side wall which separate the operating cubicle from the Storage Area are reinforced with minimum flexural steel and lacing reinforcement they will withstand (without failure) the blast output of the potential explosion. The assumed locations of the explosives are indicated in Figure 8. Post-shot condition of these walls would approach incipient failure conditions. The third wall forming the X-Ray Room is divided into two separate but parallel walls. The sum of the concrete thicknesses of these two walls is equal to the 6 feet thickness required to provide protection for the shelter area against the radiation in the X-Ray Room. The blast protection afforded by this wall will be described later.

The concrete thicknesses of the back and exterior side walls of the Storage Area are 7 feet and 6 feet, respectively. Both walls are reinforced with minimum reinforcing steel. If the amount of

reinforcement in these walls was increased then their thicknesses could be reduced. However, this increased amount of reinforcing steel would require the use of bundled bars. The handling problems incurred with bundled bars would off-set any cost reduction which would be achieved utilizing the optimum percent reinforcement.

In addition to the above described cubicle walls, an additional concrete wall is required adjacent to the open ends of the cubicles. This wall serves three purposes, namely;(1) to provide radiation protection for other on-site facilities, (2) to serve as a barricade to satisfy safety distance regulations, and (3) to provide support for the metal deck roof over the vehicle access area. This wall also serves as an end support for the rails of the overhead crane. Because this wall must provide radiation protection, its concrete thickness must be at least equal to 6 feet. An analysis of this wall indicated that, when reinforced with minimum steel, it will undergo a support rotation of approximately 10 degrees which is somewhat less than incipient failure.

Support for the above walls is provided by their monolithic intersection with one another in addition to the restraint afforded by the 3 ft.-4 in. thick concrete floor slab. The slab is continuous between adjacent interior and exterior walls in addition to being extended beyond the exterior surfaces of the building. This extension provides stability for the overall building in addition to assisting in affording the required support restraint for the exterior walls.

Openings for personnel access are required in the back wall of the X-Ray Room and the exterior wall of the Storage Area at the end of the vehicle access tunnel. Protection against radiation at the exterior of these openings is provided with the use of a single revetted earth barricade. A concrete retaining wall is used for support of the soil at the openings. The thickness of the earth barricade is equivalent to 6 feet of concrete.

The above discussion pertained to the design of the concrete walls of the X-Ray Room and Storage Area for incipient failure conditions. If limited fragment velocity (v_f = 100 fps) criteria is utilized for the above wall design, then the thicknesses of several of the walls may be reduced below those previously described. However, the alternate wall designs must consider the requirements for providing radiation protection. In the case of the Storage Area, the combined reduced thicknesses of the two side walls (alternate design 1A, Fig. 8) and the combined reduced thicknesses of the side wall separating the two cubicle areas and the back wall of the Storage Area each will exceed that required for radiation protection. On the other hand, the previous thickness of the back wall of the X-Ray Room was equal to the minimum thickness required

for radiation protection and therefore the thickness of this wall cannot be reduced using the fragment velocity criteria.

b. Shelter Area

The shelter portion of the building is a completely enclosed and self-sustaining structure. The shell of the personnel area consists of reinforced concrete walls, roof and floor slab. All personnel access opening are sealed with blast doors. Ventilation openings for both the air supply and exhaust are located in the exterior wall at the west end of the building. As will be explained later, the position of these openings relative to the ground will depend upon the Shelter's interior arrangement. The interior arrangement will also affect the plan size of the structure.

The critical element in the design of the shell consisted of the walls separating the personnel and operating areas. Initially, these walls (Fig. 8) were designed as a single element having a concrete thickness at least equal to the 6 feet required for radiation protection. In the event of an explosion this wall would undergo limited deflections (support rotations equal to or less than 5 degrees). As recommended by Reference 1 when limited deflections occur, protection for personnel against the effects of spalling can be achieved with the use of steel plates attached directly by bolts to the acceptor surface of the wall (Fig. 9).

Although the above design could have been accomplished utilizing a 6 foot thick concrete section, it was ascertained that the capacity of the wall required to achieve the desired limited wall deflection would exceed that which could be resisted by the shear wall action of the south wall. Therefore, an alternate design as illustrated in Figure 8 was developed.

The alternate design of the east wall of the Shelter consists of utilizing two separated walls; the combined thickness of which is equal to the 6 foot concrete section required for radiation. The larger of the two walls which is 4 ft.-6 in. thick, serves as the west side wall of the X-Ray Room and provides the strength to resist the blast loads produced by an explosion in the X-Ray Room. This wall is provided with lacing reinforcement in order to fully develop the flexural steel (Fig. 10). The thinner wall which is an unlaced element provides the protection against spalling for the shelter personnel. The thinner wall also serves as a shear wall to transfer the blast loads acting on the north and south walls to the floor slab in addition to providing support for the roof. Both walls are connected at their periphery thereby forming a monolithic attachment between the Shelter and operating area of the building. The maximum deflection of the blast wall will conform to that corresponding to a support rotation of 10 degrees. The two foot

space between the two walls provides sufficient room to prevent impact of the blast wall against the fragment shield wall.

The first interior arrangement of the Shelter investigated consists of a two-story building: each floor having plan dimensions equal to 26 ft.-0 in. long by 23 ft.-0 in wide (Fig. 8).

The main floor or ground level contains the personnel area (office, control room, viewing room, darkroom and toilet) while the storage and electrical areas are located on the upper level of the building. Access to the main floor is by two and one personnel access doors located in the north and west walls, respectively. An 8 ft. wide by 10 ft. high door is located in the north wall to permit movement of equipment and other material to the level of the building. Passage between the two levels of the structure is by means of a ship board type ladder located near the center of the Shelter.

In an early concept arrangement of the Shelter, the doors presently located in the north wall were located at the south side of the structure to provide easy access to the vehicle tunnel. However, the south wall, which serves as one of the main supports for the wall separating the personnel and operating areas, would be seriously weakened by these openings. On the other hand, the main support for the north end of the wall separating the two sections of the building is provided by the back wall of the X-Ray Room and therefore the north wall of the Shelter need not provide the same shear wall strength as that required of the south wall. This variation in wall strength is the governing factor for positioning the doors in their present locations.

All four concrete walls and the roof slab of the shell for Shelter Arrangement No. 1 are 1 ft. - 6 in. thick. Both the walls and the roof will, as a result of the lateral blast loads, undergo maximum deflections in the order of three quarters of an inch. The monolithic floor slab at the main floor level is an extension the 3 ft - 4 in. thick slab required for the other areas of the building while the concrete floor slab of the upper level of the building is 10 inches thick. The thickness of this latter slab is predetermined by deep beam action of the slab which transfers the lateral blast loads on the walls to the shear walls. In addition to being supported at its periphery, the roof slab is supported near its center by a 2 ft. by 2 ft. concrete column. The column extends the full height of the structure and in addition to providing support for the roof, it serves as a central support for the upper floor slab. A capital at the top of the column is used to reduce the shear stresses in the roof slab in the vicinity of the column.

As previously mentioned, the shelter portion of the structure is attached rigidly to those elements which are exposed directly to the extremely high pressures associated with the close-in effects of the explosion. These pressures will produce relatively high accelerations and velocities which are transmitted through the exposed elements to the Shelter. An estimate of the maximum horizontal accelerations is 10 and 6 g's for the roof and main floor slabs, respectively, while the maximum horizontal acceleration of the upper level floor slab is between those of the other two slabs. The horizontal movement of the main floor is similar to that of the overall horizontal motion of structure which was estimated to be equal to two inches. The roof of the Shelter sustains slightly higher displacements than that of the floor slab. Here, the flexural action of the shear wall must be added to the rigid body motions of the building.

The above horizontal accelerations and displacements are considered severe enough to produce bodily harm to the occupants of the Shelter as a result of a subject being thrown off balance. To minimize the effects of falling, protective cushioning material may be used on potential impact surfaces such as walls, floor, and interior furnishings, including flat surfaces as well as corners and edges. The cushioning material will only be required in the personnel area of the Shelter because the upper level of the structure will not usually be occupied during the time of the hazardous operation.

The second interior arrangment (Fig. 11) is similar to the first scheme except that a shock isolation platform is utilized in place of the monolithic upper floor slab of the previous scheme. In addition, the personnel area is located on the platform while the storage and electrical areas and toilets are located on the main floor. The use of the isolation platform provides a higher degree of safety than would be achieved with the use of the protective cushioning of the first arrangement.

The office and the control, dark and viewing rooms are located on the platform. Entrance and egress to the personnel area is by means of two personnel openings in the north wall. These openings lead to an exterior metal platform and stairs located along the west wall provides access from the personnel area to the lower level of the building. Access to the main floor from the outside of the building is either through a personnel door in the west wall and/or a large equipment door in the north wall. No protective cushioning or shock isloation equipment is used in the lower portion of the building.

Because of the increased span of the walls above that used in Arrangement No. 1 and the elimination of the column, the thicknesses of the walls and roof of the Shelter for Arrangement No. 2 had to be increased to two feet.

The platform consists of a series of interconnected floor beams with light metal deck flooring. Except for the dark and viewing rooms where metal partitions and roofing are used to fully enclose these areas, the periphery of the platform is provided with metal railing. Support of the platform is accomplished with the use of a series of steel spring hangers (Fig. 12). These hangers, which are equally spaced around the periphery of the platform, provide the required protection for the personnel by their ability to attenuate the horizontal motion of the structure by their pendulum action and the vertical motion by the energy absorption capability of the steel springs. To minimize the possibility of the occurrence of resonance, the upper portions of the hangers are attached to the roof slab adjacent to the support wall. To provide sufficient room for the pendulum motion, a rattle space of 6 inches is provided between the interior surface of the shell and the edges of the platform. Steel plates are used to allow movement across the rattle space at the door openings. Because the location of the equipment on the platform may change, lead ballasts located at various points on the platform, may be required. Figure 12 illustrates typical ballast stands. The weights of each stand may be removed or increased depending upon the movement of the equipment.

As previously mentioned, temperature control within the Shelter is accomplished with the use of a heating and air-conditioning unit located on the roof of the personnel area. This unit is connected, by means of a standard insulated metal duct to a air supply opening located in the west wall of the structure. The air exhaust opening, also located in the west wall, is protected from the elements by a standard ventilation cover. The location of both ventilation openings will depend upon the interior arrangement of the Shelter. In the case of Arrangement No. 1, the openings are positioned immediately below the roof slab while for Arrangement No. 2 the openings are located below the shock isolation platform. Both locations will insure that, in the event of an explosion, the jet stream formed as a result of the blast wave being focused through the openings will be directed into the storage and equipment areas and away from the personnel section of the Shelter.

REFERENCES

1. Manual for Design of Protective Structures Used in Explosive Processing and Storage Facilities, prepared for the Armed Services Explosives Safety Board, Washington, D.C. under the direction of Picatinny Arsenal, Dover, New Jersey, by Ammann & Whitney, New York, New York (Review Copy).

2. D. R. Richmond et al, The Relationship Between Selected Blast-Wave Parameters and the Response of Mammals Exposed to Air Blast, Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico, a report presented at the New York Academy of Science Conferences on Prevention of and Protection Against Accidental Explosion of Munitions, Fuels and Other Hazardous Mixtures, October 1963.

3. T. A. Breckenridge, Preliminary Development and Tests of a Blast-Closure Valve, Technical Note N-460, U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, September, 1962

Table 1 REQUIRED CONCRETE THICKNESS

CHARGE WEIGHT (lbs.)	FRAG. VEL. (fps)	CONCRETE THICKNESS (inches)				
		MAIN STRUCTURE			BARRICADE(1)	
		Side Wall	Back Wall	Slab	Wall	Slab
3750	100	42	34	22	36	21
	200	32	30	18		
2020	100	32	30	18	30	16
	200	24	21	14		

(1) Design for incipient failure

Table 2 **SUMMARY OF ESTIMATED STRUCTURAL CONSTRUCTION COSTS**

CHARGE WEIGHT (lbs)	ITEM	Building No. 1		Percent Increase	Building No. 2		Percent Increase
		v_f = 100 fps	v_f = 200 fps		v_f = 100 fps	v_f = 200 fps	
3750	Main Str.	$181,240	$133,570	136%	$95,250	$69,390	137.5%
	Barricade	73,800	70,770		43,150	42,118	
	Total	254,040	203,340	125%	138,400	111,517	124.5%
2020	Main Str.				69,390	52,600	132%
	Barricade				34,910	34,206	
	Total				104,300	86,800	121%

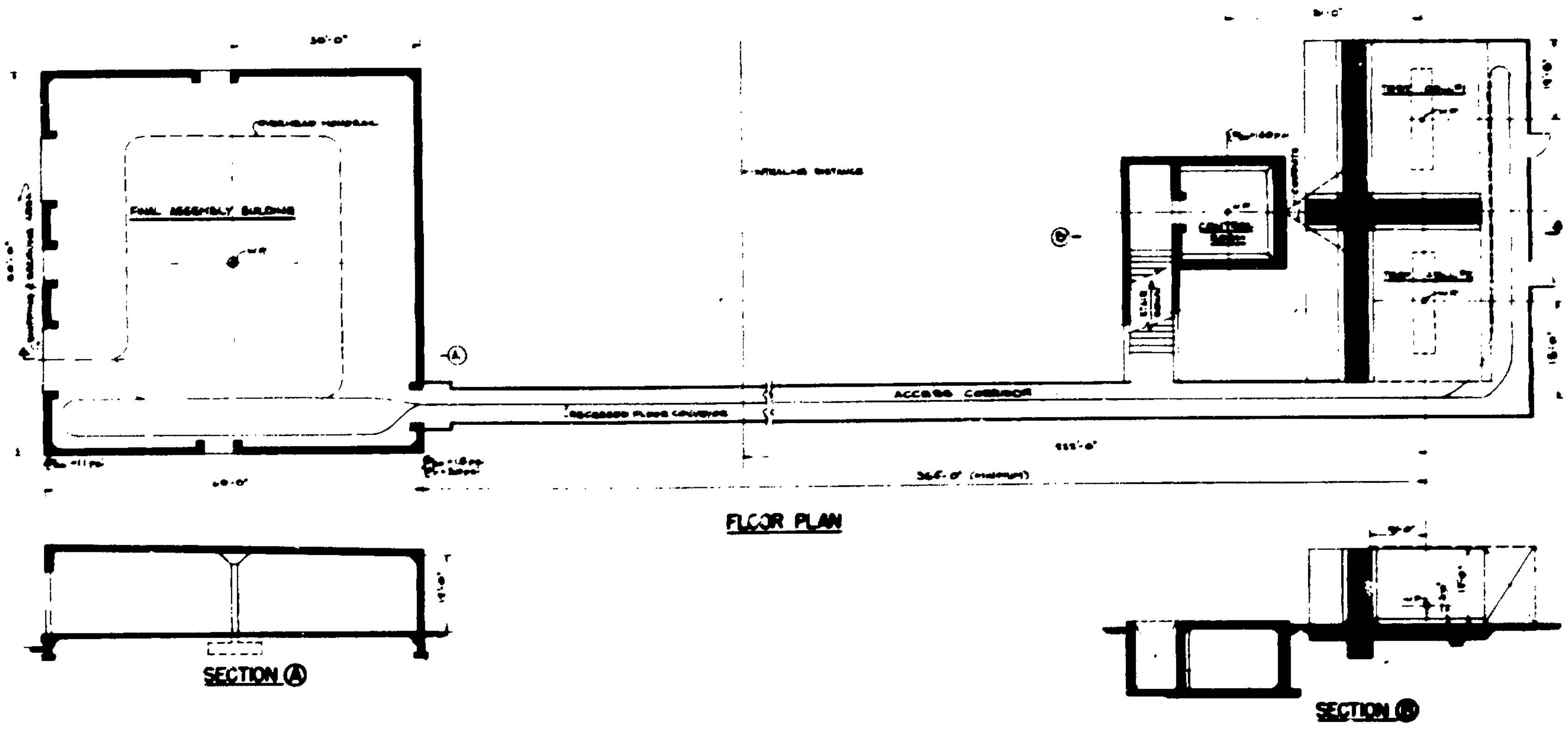


Fig. I FINAL ASSEMBLY AND TEST FACILITY SITE PLAN

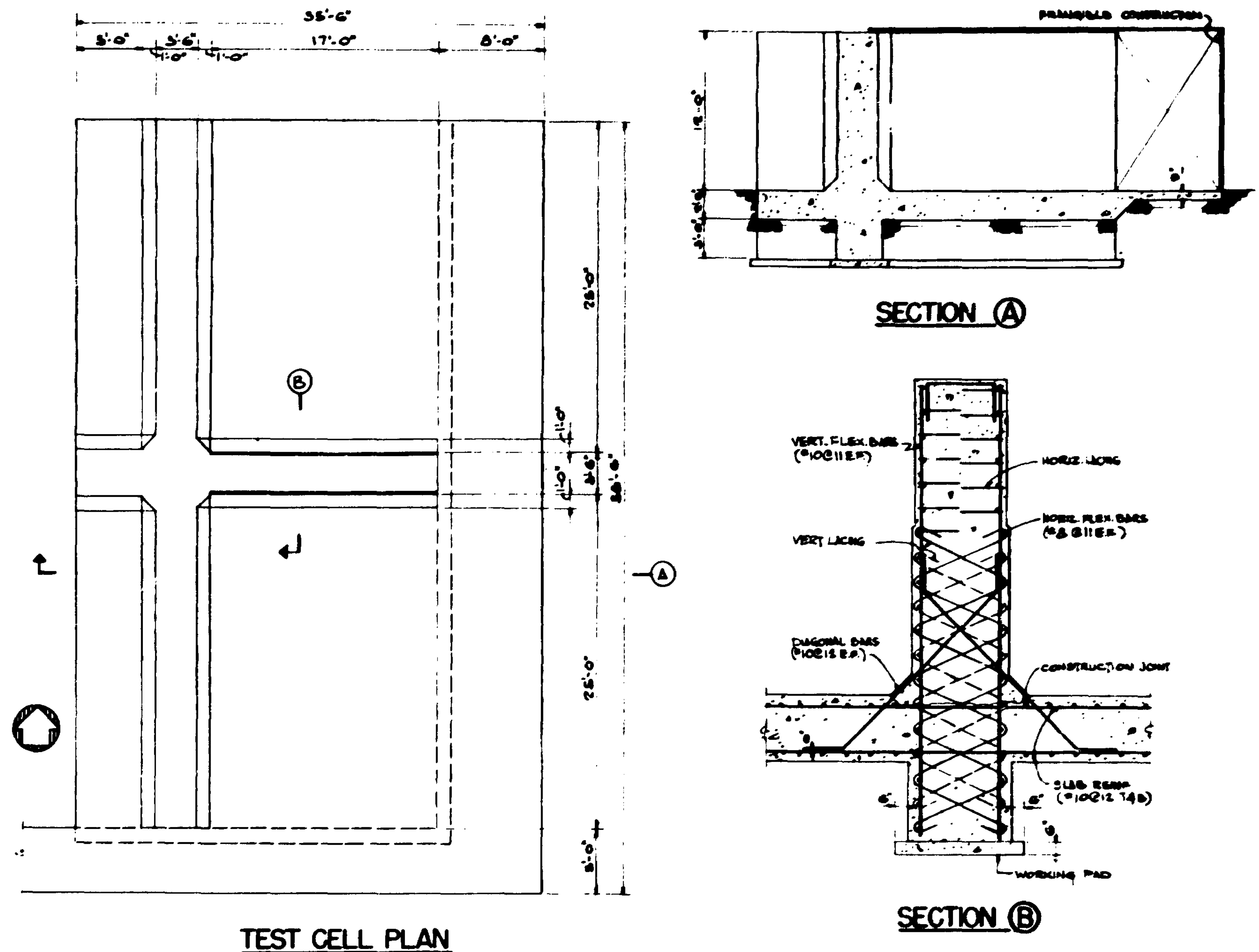


Fig. 2 TEST CELLS

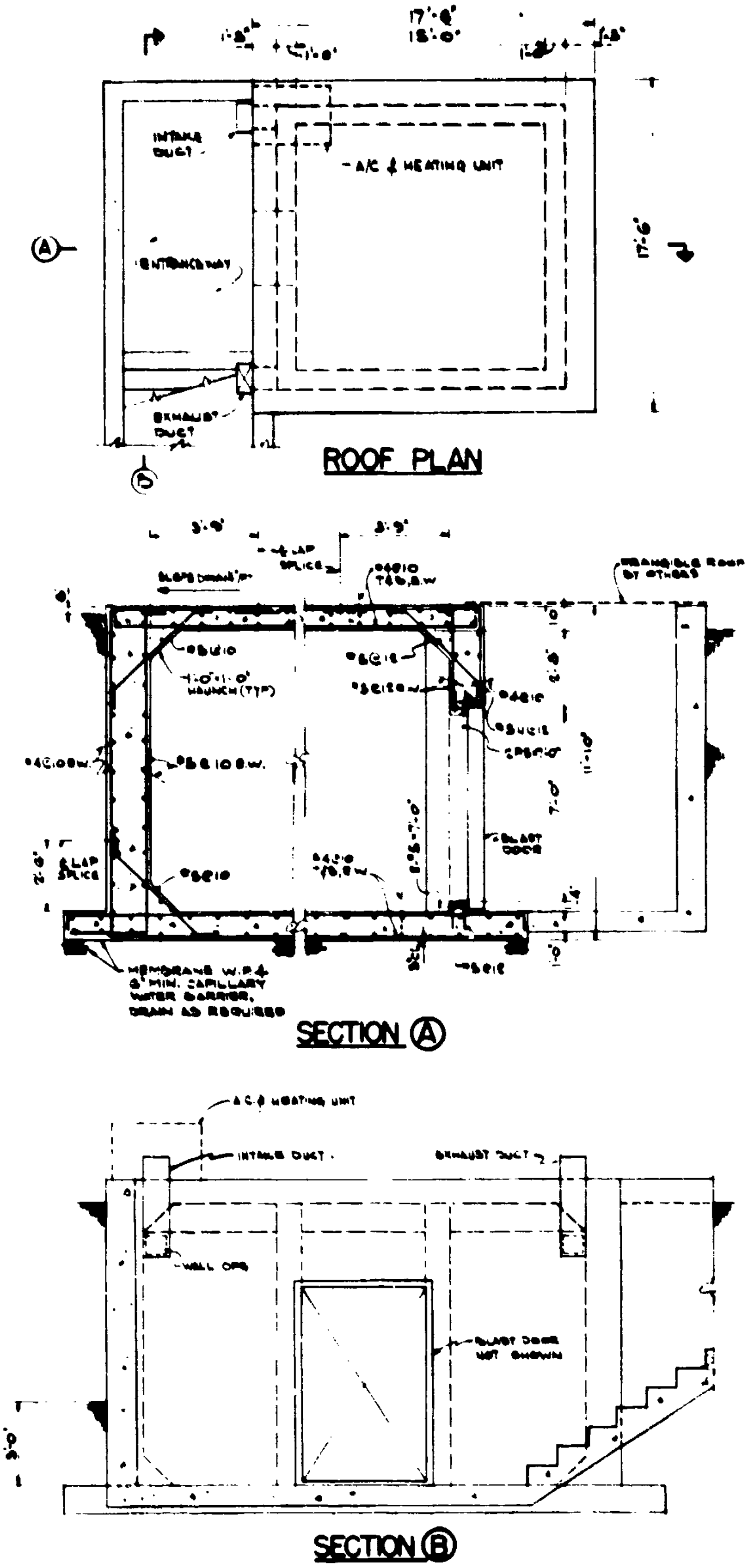


Fig. 3 CONTROL ROOM

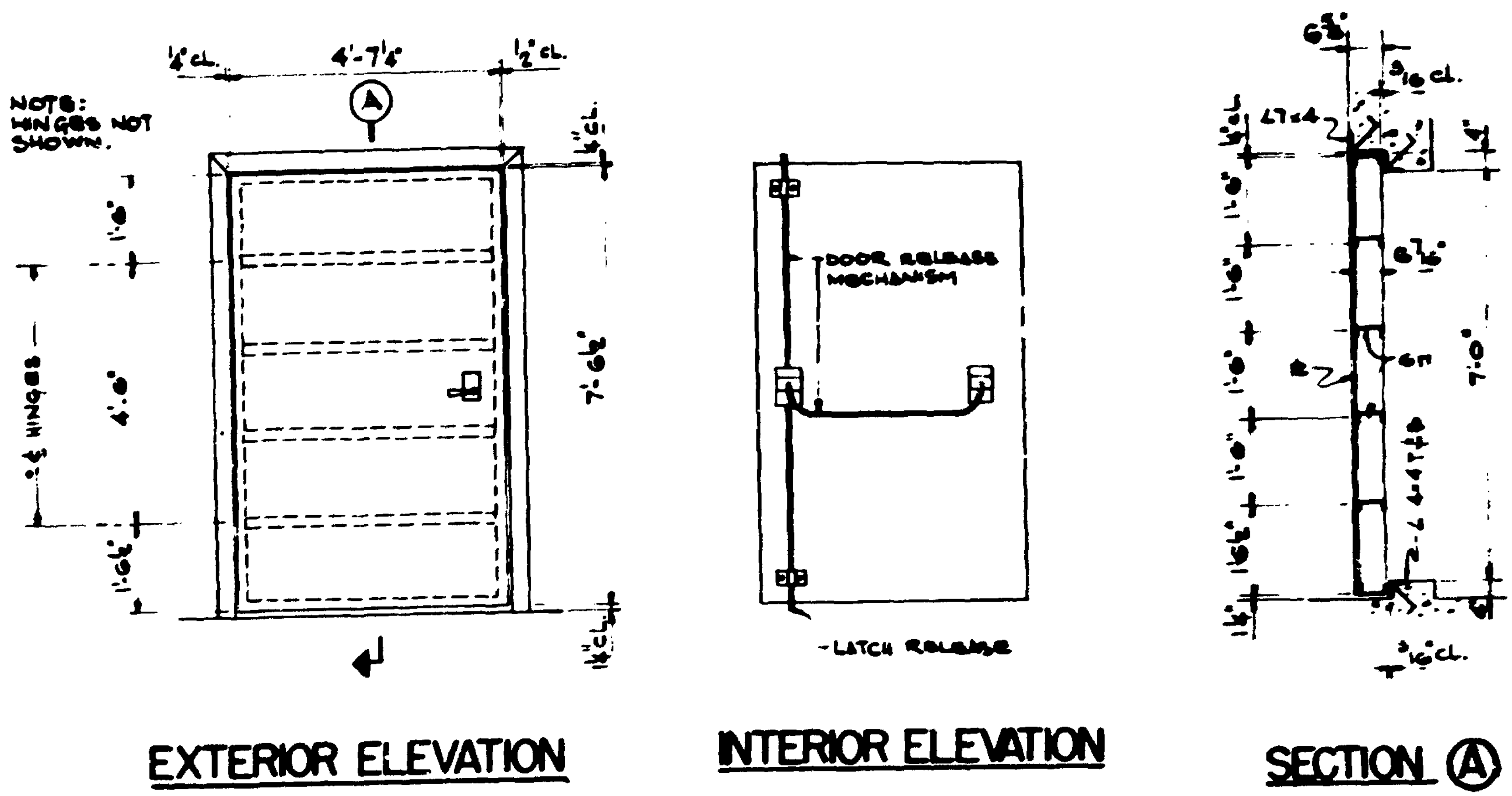


Fig. 4 CONTROL ROOM BLAST DOOR

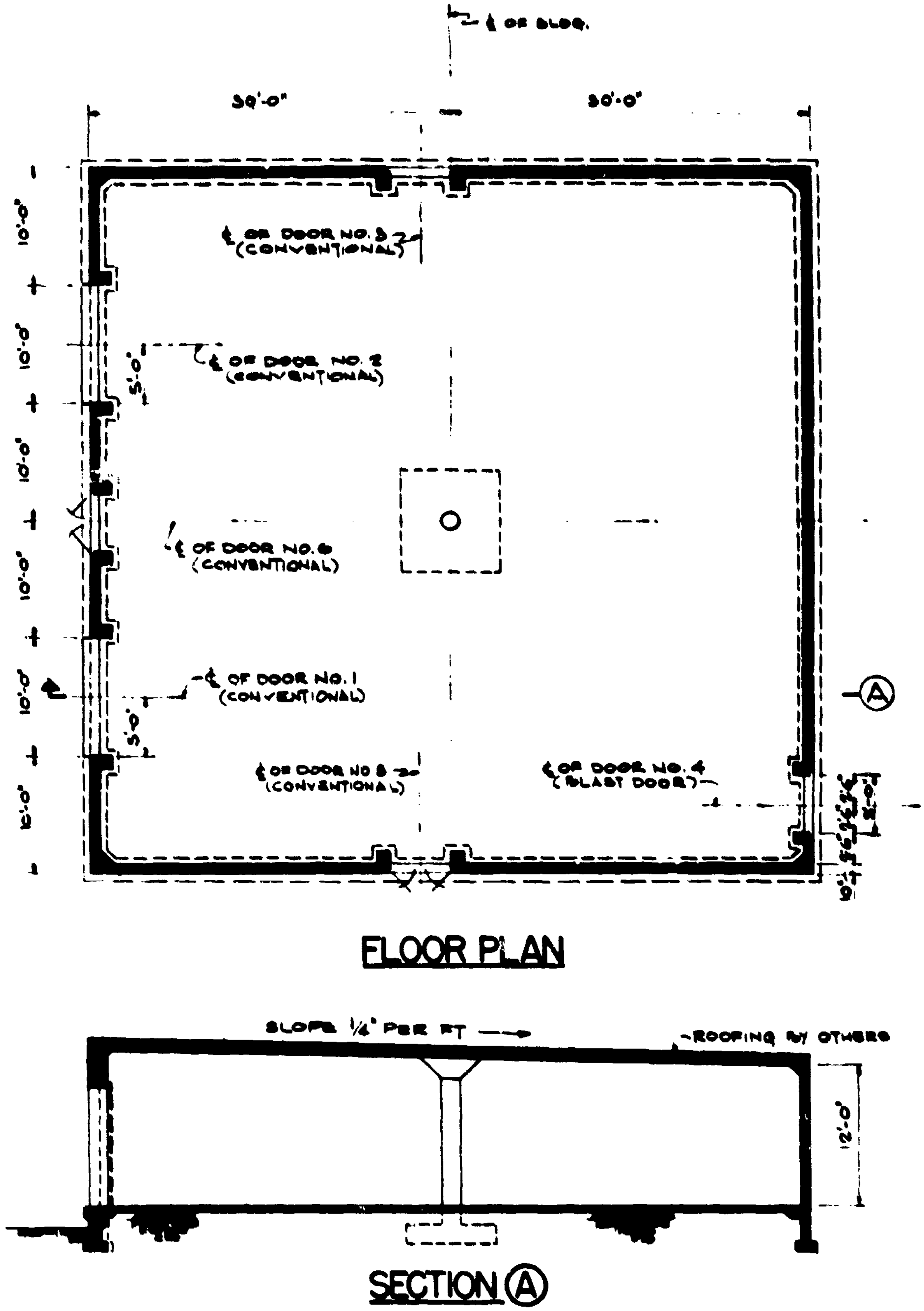


Fig. 5 ASSEMBLY BUILDING

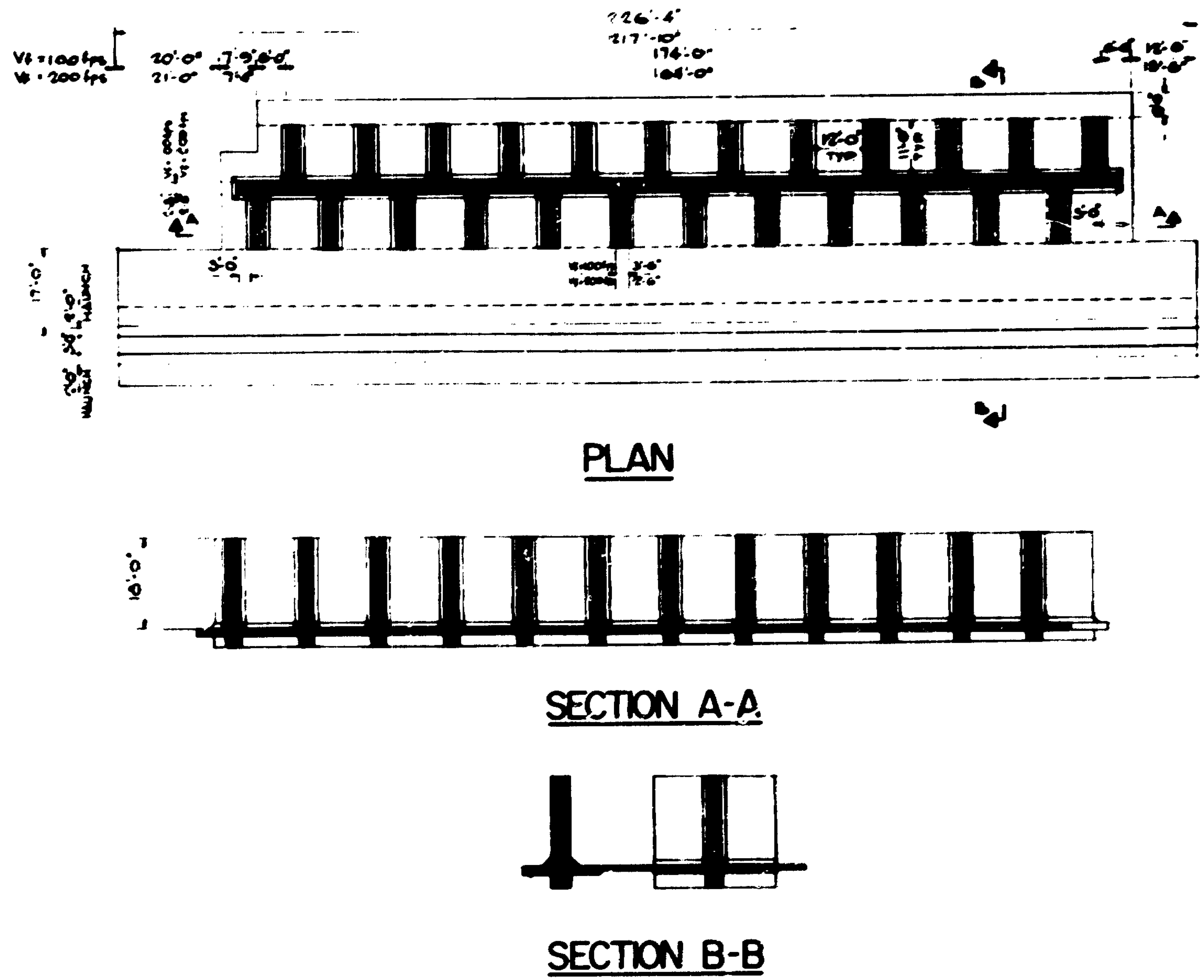


Fig. 6 CURING OPERATION - BUILDING No. 1

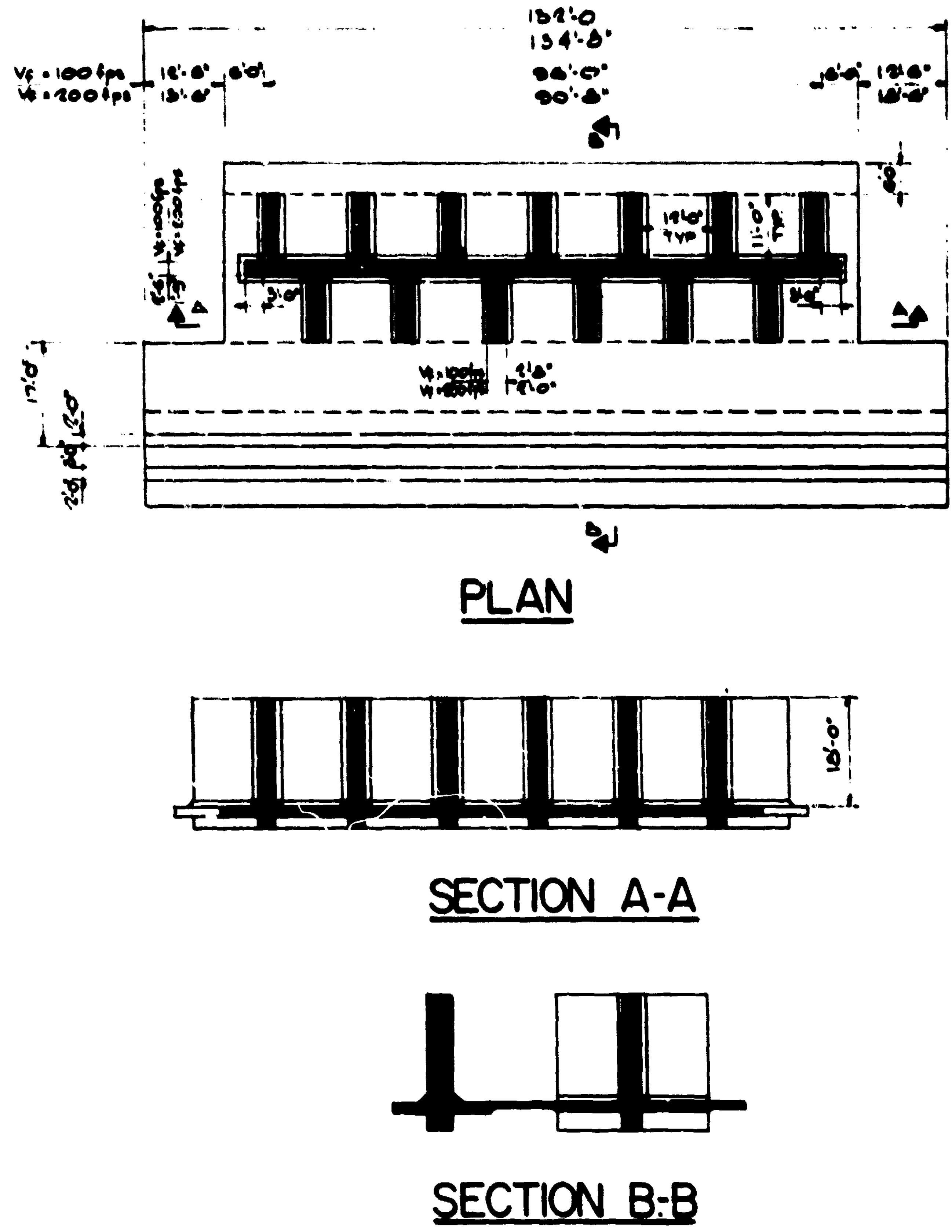


Fig. 7 CURING OPERATION - BUILDING No. 2

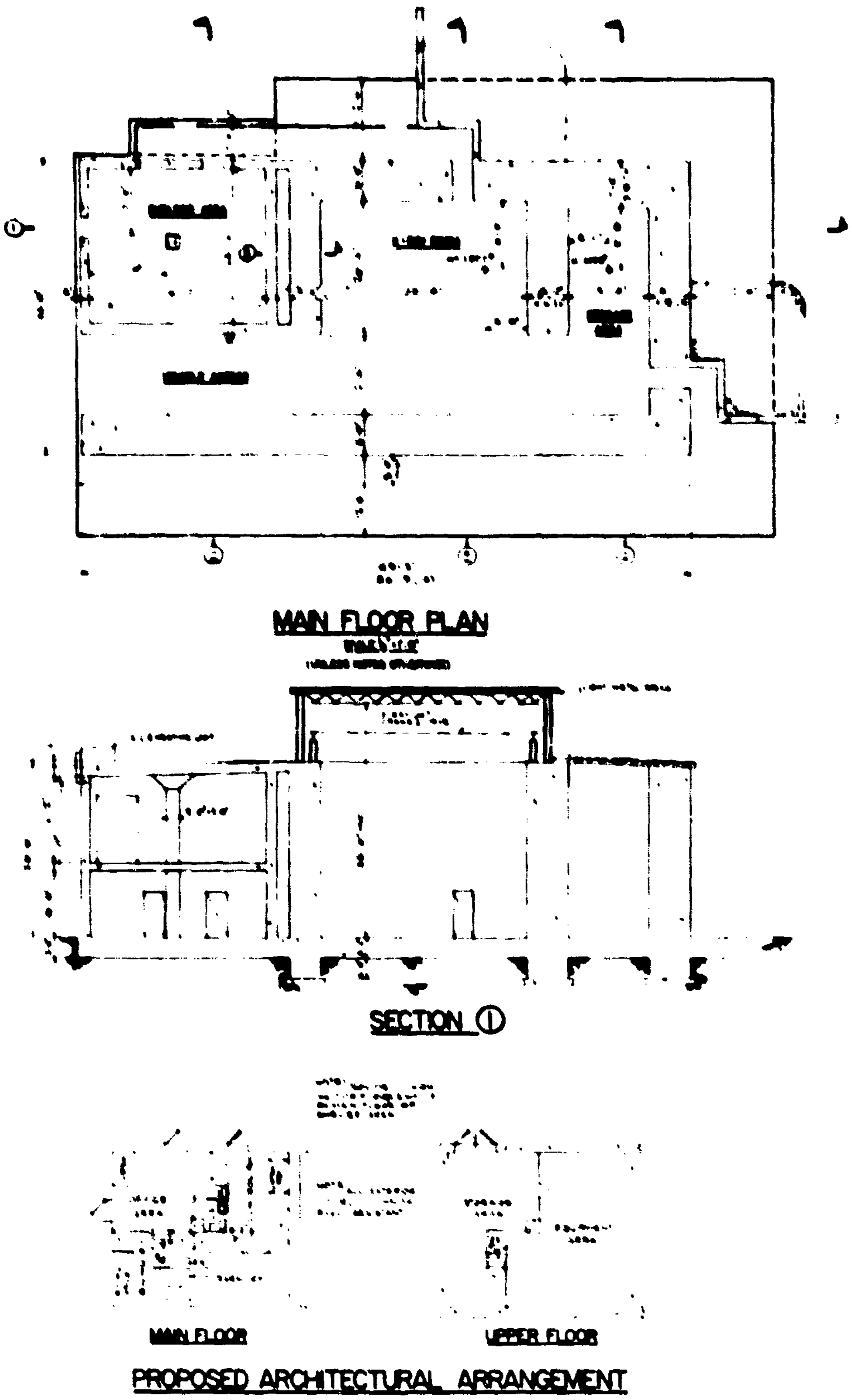
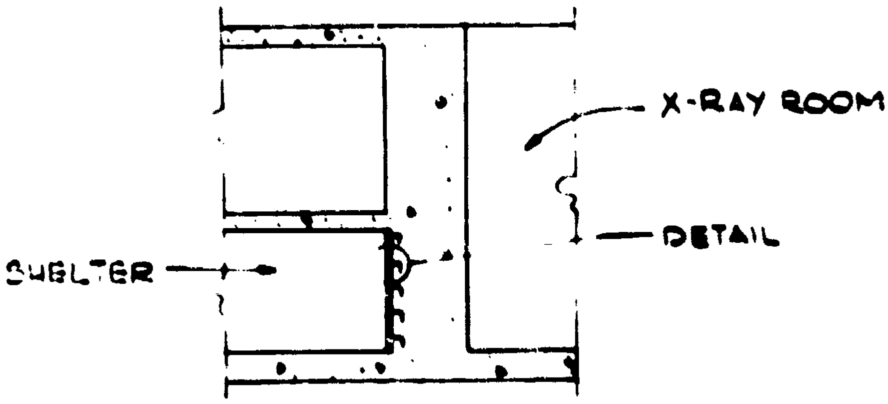
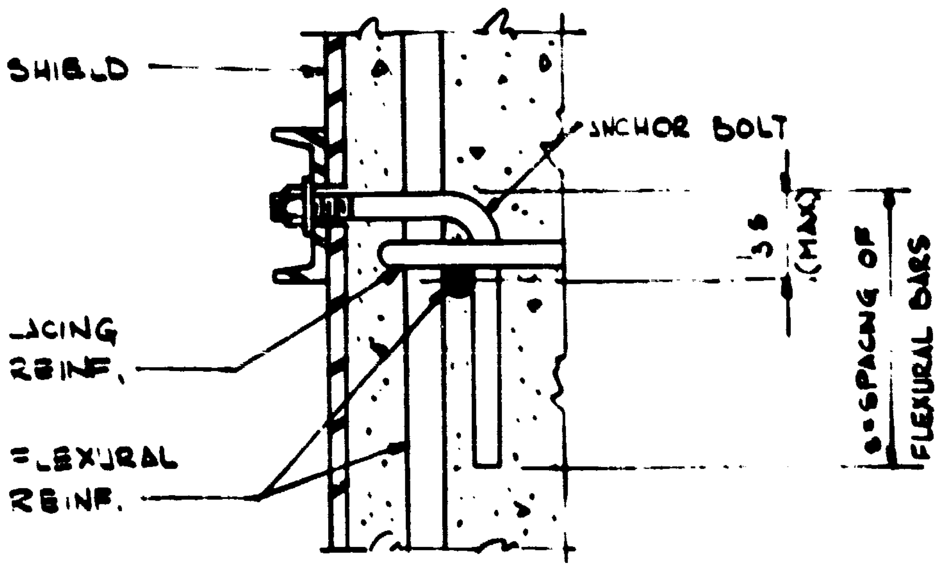


Fig. 8 X-RAY BUILDING - SHELTER ARRANGEMENT No. 1

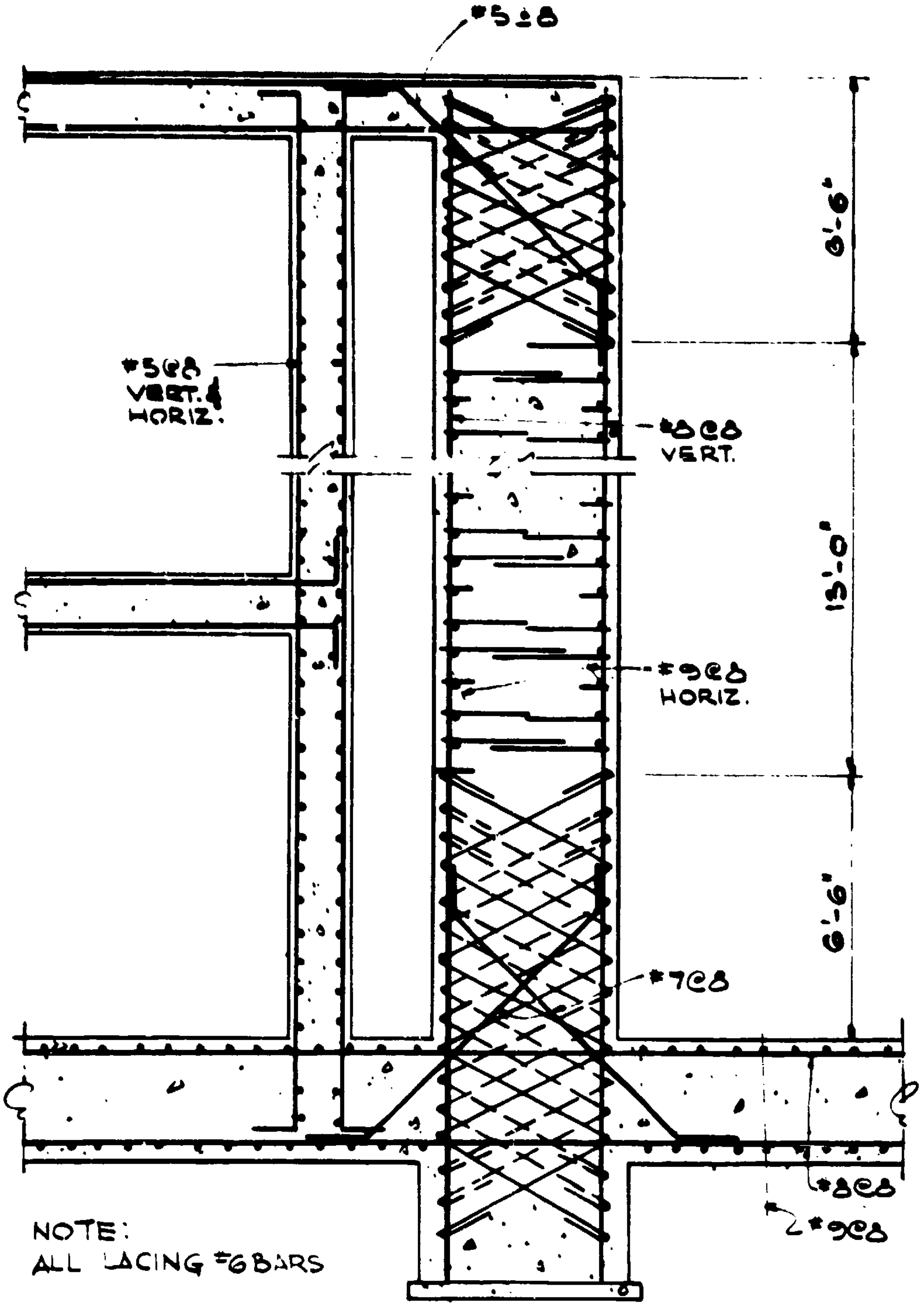


SECTION THRU WALL



DETAIL

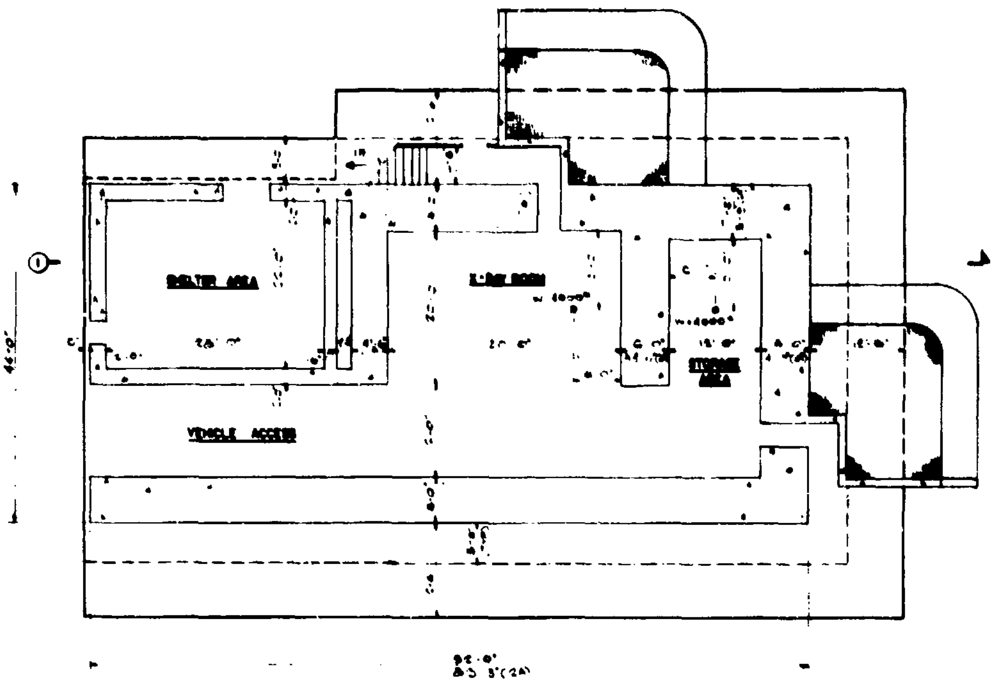
Fig. 9 RIGID ATTACHMENT OF FRAGMENT SHIELD TO DIVIDING WALL



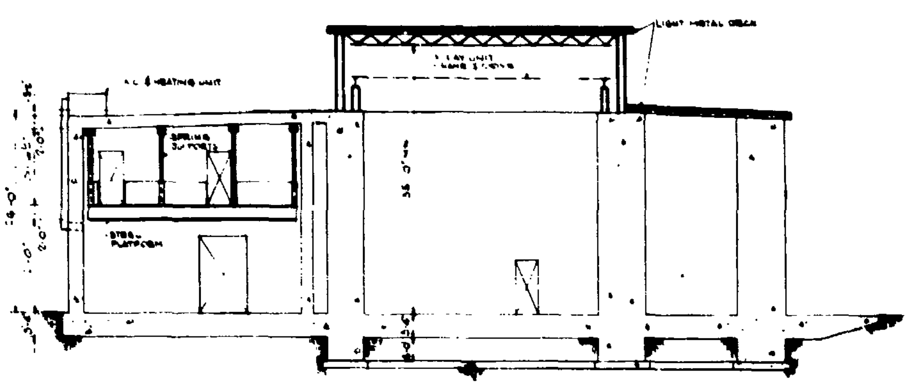
SECTION 5

SCALE: 1/4" = 1'-0"

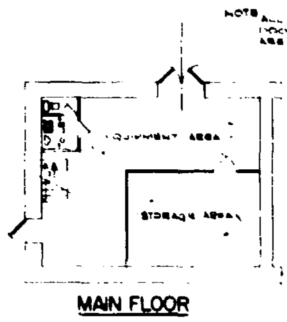
Fig. 10 DIVIDING WALL SEPARATING X-RAY ROOM AND SHELTER



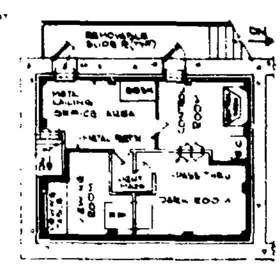
MAIN FLOOR PLAN



SECTION ①



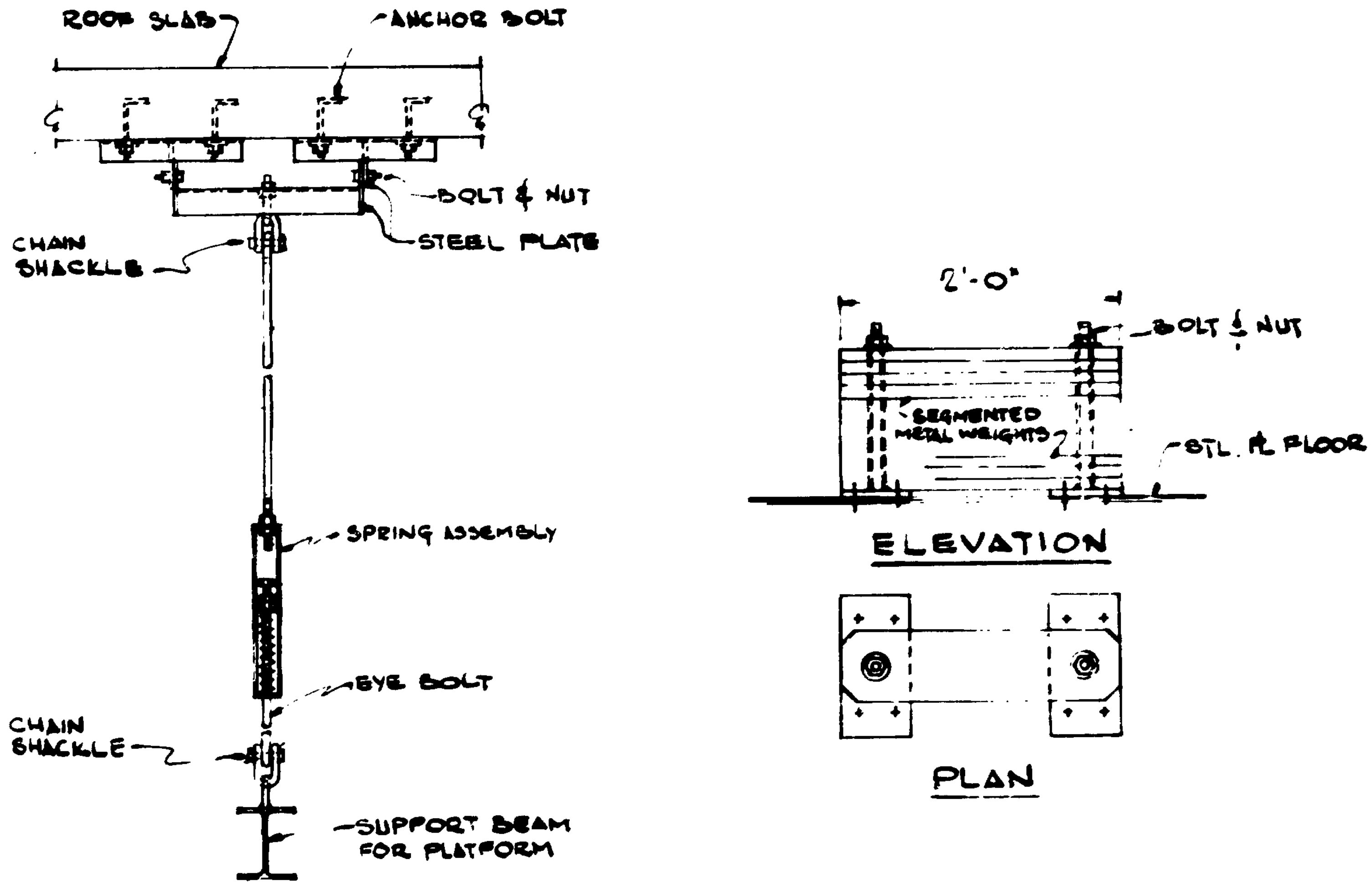
MAIN FLOOR



PLATFORM

PROPOSED ARCHITECTURAL ARRANGEMENT

Fig. 11 X-RAY BUILDING - SHELTER ARRANGEMENT No. 2



HANGER DETAIL

BALLAST DETAIL

Fig. 12 TYPICAL PLATFORM HANGER AND BALLAST DETAILS

LIMITING EXPLOSIVES ACCIDENT EFFECTS IN OPERATING BUILDINGS*

by

I. B. Akst

Mason & Hanger - Silas Mason Co., Inc.
Pantex Plant, Amarillo, Texas

Could new criteria or new designs for explosives buildings increase operational safety profitably? Perhaps we can tell by reviewing some of the reasons, criteria and practices in safety.

Probably we practice safety for two main reasons: because it pays to and because we ought to. In other words, for money, time, productivity; and for purely human reasons such as survival and protection from misfortune and discomfort.

If those are reasons for safety, they should be guides in the practice of safety. An obviously good practice is to limit the occurrence of accidents. If we could reduce the probability of occurrence to zero, then we would not need to be concerned with the effects of accidents. Of course, a great deal is done to keep the probability low; but it is not zero and never will be. Therefore, we should strive to limit effects as we limit occurrence.

----

*Auspices of the U.S. Atomic Energy Commission.

What we wish to do now is to examine the degree to which we limit effects, and whether we should change the degree. A glance at safety manuals or procedures for explosives operations will show that many of the regulations are aimed solely at limitation of effects. For example, plants processing explosives are placed away from centers of population wherever possible. We also protect one building from another by spacing them apart so that an accident will not propagate, as for example in the Lake Denmark accident of many years ago. We also do such things as putting up barricades, limiting amounts of explosives and insisting that some operations be done remotely. All these things have nothing to do with the limitation of occurrence of an accident, but only the limitation of effects.

These regulations are efforts to limit accident effects to the area of origin; and they do that to a good degree, in general restricting the effects to one building. They do not, however, limit the area of effects to the ultimate, which would be the region immediately outside the explosive itself. (That is almost attained in some small operations, such as loading detonators.) Our postulate is that we can draw other circles of limitation between the existing and the ultimate and can find at least one which significantly reduces effects, at a cost which is tenable. Our goal will be to try to limit the effects on people, facilities and productivity to the smallest possible circle. We will mention one or two methods for achieving this, and describe a solution which seems to do much of what we want, in some kinds of operations, without spending exorbitant amounts of

money. The cost of achievement is crucial: after all, what we are talking about is the amount of protection we are willing or able to buy. No one would argue against total protection if it were free and carried no penalty. But it isn't free; quite the opposite, and so we have to make careful choices.

One of the choices, for example, is remotely controlled operation. Remote operation limits effects on people, but is not in general applied so as to limit effects on facilities or productivity. It is often a good solution for operations involving relatively simple motions and repetition, like pressing or machining. It can be difficult and expensive in assembly types of operations.

Other choices can be thought of (for example—forgive the thought—body armor). But one choice seems to stand out as being effective—that is, able to limit the circle of effects to a small size—at reasonable costs. That choice is restricting the effects to the bay or room of the accident by means of the structure itself, i.e. by design or construction of the building.

We should define a little more carefully what we will accept as fairly complete limitation of effects. We will consider these criteria as governing: (1) no one will be killed or seriously injuried beyond the bay or room of accident and immediate area (meaning close to the entrance and exit); (2) there will be no major equipment or facilities damage beyond the immediate area of the bay; (3) disruption of production will be minimal, and (4) other effects such as the spread of hazardous materials

will be held to a minimum consistent with the above aims and cost.

Can these limitations be effected in present buildings by simple protective techniques or by scheduling? The answer is that they cannot in most present AEC HE facilities at present production rates. Neither could they in most other other ordnance explosive facilities.

Can these buildings be modified so as to attain the aims? The answer is that we do not know with certainty how to do it at costs competitive with new construction.

If we were to build new operating buildings, would we know how to build them so as to attain these aims? The answer, I believe, is yes, for some kinds of HE operations. A potentially powerful design for doing this is the multiple steel arch earth-covered structure. Tests conducted at NWC under the auspices of the Armed Services Explosives Safety Board[1] showed that this kind of structure has considerable intrinsic safety. The tests at $D = W^{1/3}$ (where W is the weight of explosives in pounds and D is clear distance in feet between the arches) showed that propagation of an explosive accident would not occur at this spacing and that damage to adjoining structures was much less than total. At a distance of $1.25W^{1/3}$, little more than slight bending of the corrugated steel took place.

A principal cause of death beyond the bay of accident in many of today's

----

[1]*Summary Report of Earth Covered Steel Arch Magazine Tests; NOTS TP 3845, July 1965.*

ACC HE structures will usually be from collapse or from debris propelled or being thrown through the air.[2] The strong earth-covered arch would prevent virtually all of these, so that the lethal range would revert to that caused by blast pressure. Unfortunately, the NWC tests did not show what the blast pressures were inside the contiguous arches, since instrumentation of that kind was not applied. At doors in the center of 13 ft. radius arches spaced 1.25 to $2.0W^{1/3}$, free-field blast would be on the order of 30 psi peak overpressure from 300 lbs. of HE, 60 psi from 1000 lbs.

Until recently, the critical blast pressures for death and permanent injury were not well known. But now it appears that the following three figures are reasonably good estimates for humans[3]: 5 psi peak overpressure for incipient injuries such as minor ear bleeding, 15 psi for permanent injury, and 50 psi for 50% fatalities.

It seems altogether possible to put together, affordably, an array of such structures so that many kinds of HE operations can be conducted with a good degree of economy and efficiency, and with the safety described above. The sketch shows one such possible arrangement. The blast doors keep

---

[2] *Study Report, Plutonium Limits at Assembly Plants (U); R. L. Miller & T. R. Crites, Sandia Corporation, July 1966;*

[3] *See, e.g. Glasstone, "Effects of Nuclear Weapons": or C. S. White & D. R. Richmond, "Blast Biology". Tech. Programs Rept., Sept. 18, 1959, Lovelace Foundation (TD-5764, Biology & Medicine).*

pressures in the ramp or corridor low; the back doors blow outward to vent, and also serve as quick emergency exits. If these are made strong enough to withstand the pressure from the outside—i.e. not blow inward—then the occupants of adjoining bays would be almost completely protected against serious injury (perhaps with the exception of an object being dropped through startle effect and similar low probability incidents).

The small cubicles between bays can be used either for storage or for remote operations consoles if that is sometimes desirable. Each bay should have individual utilities modules, e.g. air conditioning, vacuum, and air pressure (electricity, communications, water, etc. must no doubt be central) to limit the effect on facilities and disruption of production. For example, avoidance of air conditioning ducts greatly reduces transmission of damaging pressure pulses and hazardous materials through the buildings. The back entrance can serve for delivery of materials or equipment and tools as well as an escape.

The barricade wall just outside the back doors is to limit the trajectory of missiles to high angles, thus reducing range and hazard to other parts of a plant or the public.

Some other potential advantages of such buildings are protection against severe weather and suitability as fallout shelters. Also, the scavenging effect of earth cover has been shown[4] to be significant so that this kind

---

[4] *Roller Coaster Interim Summary Report, DASA POIR-2500, Vol. 100, Sept. 1963;*

of structure has an advantage in the scatter of hazardous materials outside the building.

The cost of these buildings has been estimated variously from less than to as much as twice "standard" 1-foot concrete dividing wall construction. No detailed estimate has been made on the operating costs. My opinion on costs—derived from too little experience to call them judgments and too much experience not to express them—is that construction would not cost more than an additional 25%; there is even a possibility of saving in land, road or fence costs since siting might be much closer. Operating costs would be comparable to present ones in many kinds of operations. Maintenance would be about the same, and repair costs for natural or accidental disaster would be an order of magnitude less.

With regard to the last, one might review the letters of D. Johnstone[5] and V. Vespe[6], and the study of Miller & Crites[2] on the effect of an accident in an assembly building, or do some exercises on the maximum possible liability to understand the great potential for saving in lives and dollars in the event of an accident.

I am happy to report that this concept is no longer a paper one. The idea has been implemented in a small way in an R & D area at the Pantex AEC Plant, Amarillo; one bay of a six-arch complex serves for packing and

---

[5]*Possible Substitution for Gravel Gerties (U), April 20, 1966;*
[6]*Plutonium Limits at Assembly Plants (U), June 8, 1966 & July 19, 1966;*

shipping, another for radiography and the rest for storage. The multi-arch design is also to be used soon to house a new and somewhat more hazardous test on an HE assembly. And a third set of structures is planned for the near future using the same effect limitation concept but a rectangular reinforced concrete earth covered design.

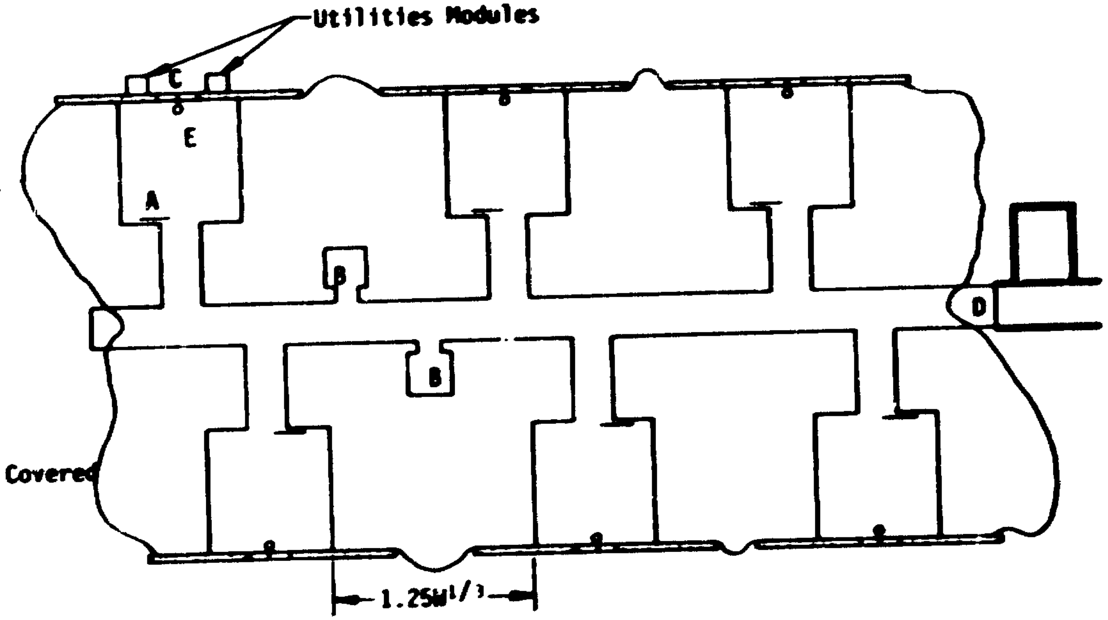
So accident effects limitation is progressing, not only by these designs and studies, but also to one degree or another, by other designs such as the strong walls by Picatinny Arsenal/Ammann & Whitnay. It is recognized that many kinds and sizes of operations are not very amenable to these ideas, or the cost of implementation would be too great for the returns. But maybe there are many places I'm not aware of that effect limitations could be implemented. It ought to be worth a look.

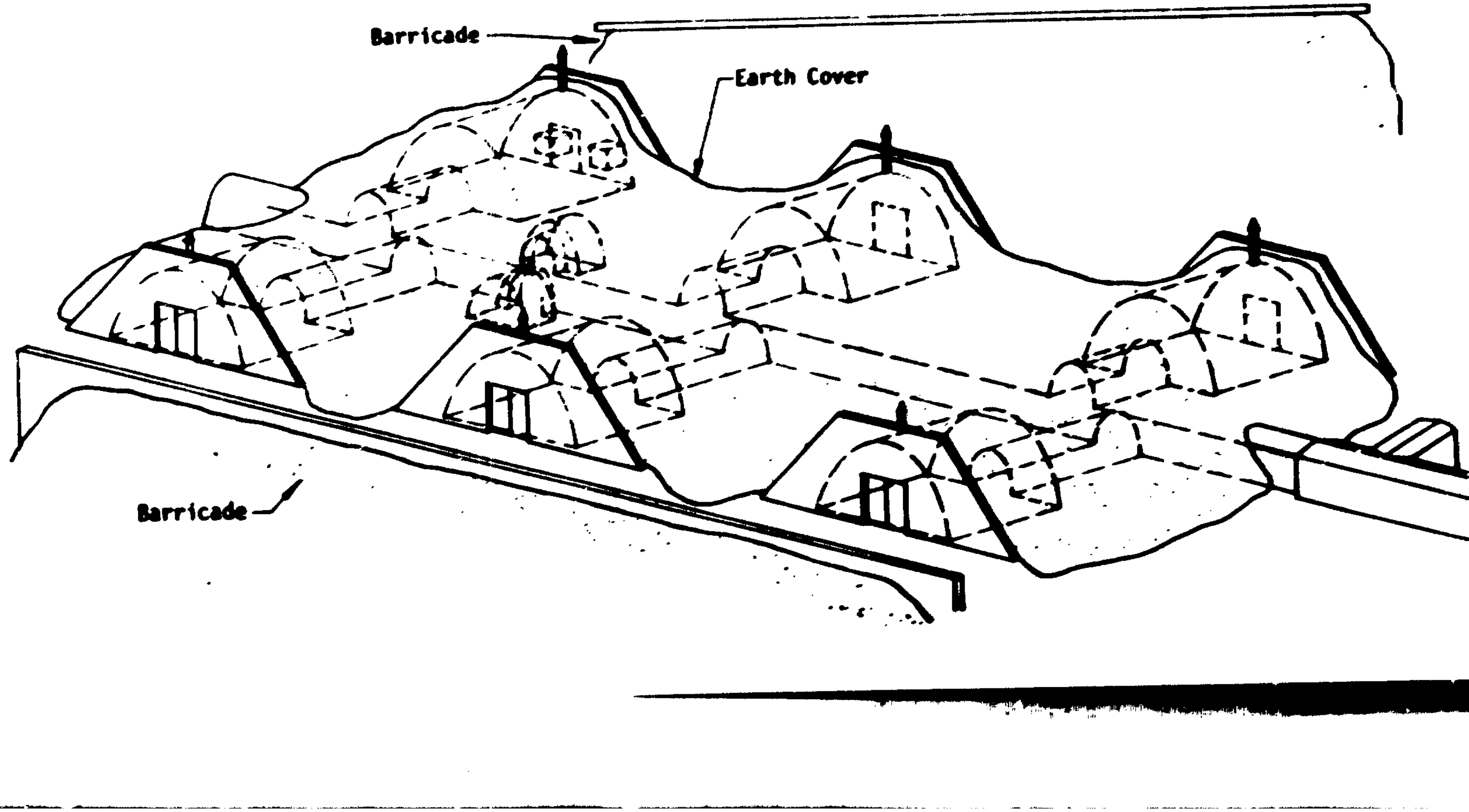
CONCEPTUAL DESIGN FOR HE OPERATIONS

BUILDING

A. Blast Door
B. Remote Console or Storage
C. Escape Door
D. Entrance Tunnel
E. Vent Pipe

—— Steel Arch Const. Earth Covered
═══ Standard Const.
═══ Concrete Const.





FACILITY DESIGN FEATURES FOR ASSEMBLY, SURVEILLANCE AND INSPECTION BUILDING OF MINUTEMAN RE-ENTRY SYSTEMS

by

Harry L. Callahan
Black & Veatch Consulting Engineers
Kansas City, Missouri

Report "FOR OFFICIAL USE ONLY" and may be obtained from:

Hq Space & Missile Systems Organization (AFSC)
ATTN: SMEA
AF Unit Post Office
Los Angeles, California 90045

NEW R&D EXPLOSIVES ITEMS WHICH MAY

AGGRAVATE EXPLOSIVES SAFETY PROBLEMS

Moderator: R. J. Billingsley
Armament Development and Test Center
Eglin Air Force Base, Florida

A LOOK AT EXPLOSIVE SAFETY FROM THE R&D VIEWPOINT

by

R. J. Billingsley
Armament Development and Test Center
Eglin Air Force Base, Florida

This paper is "CONFIDENTIAL" and is

contained in Volume II.

NEW R&D EXPLOSIVE ITEMS WHICH MAY AGGRAVATE EXPLOSIVES SAFETY PROBLEMS

by

LTC Morton Fischer, USAF
Air Force Armament Laboratory
Eglin Air Force Base, Florida

This paper is "CONFIDENTIAL" and is

contained in Volume II.

HAZARD CLASSIFICATION OF SOLID PROPELLANTS

Moderator: Dr. Billings Brown
Institute for Defense Analyses
Arlington, Virginia

HAZARD CLASSIFICATION OF SOLID PROPELLANTS

SUMMARY

Dr. Brown presented, in a lead-off paper, data showing that the handling hazard for composite (fuel binder) solid propellant motors is mainly from scattering of burning propellant over a wide area following impact. The majority of these data were obtained from "accidental testing." The energy inputs of concern range upward from that required for propellant ignition, the most serious incident occurring from the fallback of a rocket motor following launch. Detonation of motors containing composite propellants is nearly impossible to achieve; however, explosive reactions are easily initiated by impact energies available in accidents.

Dr. James Wiegand of Aerojet presented his analysis of Project SOPHY data to illustrate the fading detonation that occurs when composite solid propellants are exposed to a high velocity shock wave in the NOL Card Gap Test configuration. The portion of the confining pipe nearest the explosive donor always shows failure in shear, expected for a detonation. The pipe further away from the donor fails in tension, thus witnessing a subdetonation, explosive reaction. Dr. Wiegand thus reaches the conclusion expressed earlier by Dr. Donna Price: When a sustained detonation does not occur, the NOL test results as presently interpreted (the witness plate must shear) have no meaning. Dr. Wiegand feels that it is not enough to ask "does the propellant detonate?" Rather we need to know the extent of the fire hazard. Data were shown in support of the Aerojet recent modification of the bullet impact test, which shows remarkably little spread in the test data, differing in this important respect from the usual impact tests. His final conclusion was that a useful propellant hazard classification test should relate to the intended use.

Dr. Charles Dale of NOS Indian Head commented on the flying plate test results, urging uniformity in this test. He is obtaining significant explosive yields from 10 lb. propellant samples in his testing. Dr. Dale is seeking a correlation between propellant mechanical properties and the results of his flying plate tests conducted near 500 ft/sec.

Mrs. Hyla Napadensky of IITRI reported that a computer code was recently completed at IITRI under an AFOSR contract to model the effects of impact on propellants at large deformations. A report will be issued soon. She also recollected that the SOPHY program was originally scheduled to investigate subdetonation reactions; however, the funds were cancelled.

Capt. L. R. Olsen, USN (Commanding Officer, NOS Indian Head, Md. and Navy Member, Armed Services Explosives Safety Board) suggested that the group recognize the invalidity of present tests and urged that specific proposals be made to ASESB recommending appropriate meaningful tests.

EXPLOSIVES TRANSPORTATION PROBLEMS--
LAND AND WATER

Moderator: Alfred Fernandes
Naval Ordnance Systems Command
Washington, D. C.

EXPLOSIVES TRANSPORTATION PROBLEMS--LAND AND WATER

SUMMARY

During this session, Mr. S. E. Weaver, President of Weaver Associates, Inc., made a presentation relative to the use of a specially developed device capable of rendering rocket motors non-propulsive during transport and storage if emergency warrants.

Report No. 1045 "Development Summary Report - Solid Propellant Rocket Automatic Thrust Terminator" August 1968. Available from Weaver Associates, Inc., 378 Cambridge Avenue, Palo Alto, California 94306.

LEGAL ASPECTS OF ACCIDENTS

Moderator: Bruce M. Docherty
Assistant General Counsel
Office, Secretary of the Army
Washington, D. C.

LEGAL ASPECTS OF ACCIDENTS

SUMMARY

The session was devoted to the discussion of a number of legal problems which might arise from accidents, or from the hazards inherent in the manufacture, storage or transportation of explosives. There was an exchange of views and information, but no attempt to answer specific questions on actual legal problems. It was suggested that any such questions be addressed to the participants' own counsel.

Each of the panelists made an extemporaneous presentation. Mr. Crowley discussed products liability as affected by the Uniform Commercial Code, state laws with penalties for "willful and intentional misconduct" and nuisance liability problems in running hazardous operations. Mr. Jezek reviewed a number of cases in which contractor employees who were injured in accidents had sued the Government. He described in particular the problems he had encountered in such cases in his capacity as an expert witness for the Government. Mr. Turk discussed safety and health standards for Federal supply contracts under the Walsh-Healey Act. He commented upon the regulations issued by the Department of Labor in this area and in particular described the effect of those regulations on the activities of Government Owned-Contractor Operated plants, the so-called GOCO operation.

There were also comments by other participants, and questions directed to the panelists both on their presentations and on related topics. The general discussion covered a wide range of subjects. Included were the special problems involved in bringing suit against the Government; the Federal Tort Claims Act; the doctrine of sovereign immunity and the circumstances under which that doctrine may be invoked by a defense contractor; the effect of the Federal Employees' Compensation Act when a Government employee is injured on the job; the impact of state Workmen's Compensation Acts; and the question of whether a Government safety officer might be personally liable to an injured Government employee.

A number of recent lawsuits resulting from accidents were also discussed. It was observed that the outcome of such cases may vary depending on whether the Government or the contractor owned the plant where the injury occurred. Another factor which may affect the result is the status of the person injured, i.e., Government employee, contractor employee, adjoining landowner or simply a member of the public with no special relationship to the Government or a defense contractor. There was also some discussion of the extent to which the Government's liability might

be affected if Government officials give instructions to a contractor's employees with regard to contract operations, or issue safety regulations for the protection of the contractor's employees.

The moderator considers that the session was valuable in identifying and exploring, to the extent that time permitted, a number of the legal pitfalls which are inherent in extrahazardous activities carried on by the Government and its contractors. The moderator wishes to express his sincere appreciation to the members of the panel and to all the other participants in the session.

EXPLOSIVES SAFETY REGULATIONS AND CRITERIA

Moderator: J. J. Molloy
North American Rockwell Corporation
Aerospace and Systems Group
El Segundo, California

EXPLOSIVES SAFETY REGULATIONS AND CRITERIA

SUMMARY

The following comments were prepared by the participants of subject session:

1. Mr. Willis J. Baldwin, Safety Engineer, DCAS.

a. DCAS does not have any contract safety regulations, criteria or requirement.

b. The DCAS mission is solely to administer the safety aspects of the contract as spelled out within the terms of the contract.

c. DCAS is as anxious as you to see the new DOD Manual for ammunition, explosives and related material contracts.

d. There is no DSA/DCAS Contractor Safety Manual.

e. Some contractor safety people tell me that it is impossible to comply with the safety requirements of some contracts. These people allege their contract people will sign any contract regardless of the safety requirements. All I can say is that the Military Departments and NASA, have delegated the responsibility of the administration of the contract to DCAS. The Military Departments let the contract. The company signed the contract. The company agreed to perform to certain requirements and DCAS is only going to assure that you are complying with the terms of the contract.

2. Mr. Donal Endsley, DIG for Inspection & Safety, Hq USAF, Norton AFB, California.

a. History of the Air Force Explosives Safety Manual, AFM 127-100, was outlined. It was recalled that due to accelerated evolution that occurred when we broke our munitions out of storage bunkers and loaded it on our aircraft in the 1950-60 time-period to meet the rapid defense missions, we found that the Army Manual could not serve our purposes in accident prevention. Likewise, production facilities were faced with new and challenging problems dealing with extremely large quantities of chemicals, liquid and solid propellants, for our space and missile systems. The Army Manual did not cover these situations adequately. Therefore, the Air Force Manual was developed. Some of the participants in this Seminar may recall the Air Force convened a series of meetings with Service representatives and contractors to assist in the preliminary

review and development of the Explosives Safety Manual. Needless to say, from these early efforts our manual has not been in a dormant state. We are continuously reviewing and revising, as required, consistent with changes in operations and missions.

b. Site plan development, submitted and review. Some of the common faults we in the Air Force find involving site plans correspondence was outlined, such as poor quality of maps, facilities not identified, quantity and class of explosives not included for all facilities under review, and inadequate copies of maps. All participants having business with the Air Force were encouraged to assist in improving site plan correspondence in furtherance of expediting their requests for approval.

c. Safety verification program for non-nuclear munitions. A brief outline was presented on our concepts under consideration to establish a Non-nuclear Munitions Safety Verification Program. It was our intent, if this program is adopted, that all Services and contractors would have an essential and vital input to the program regarding the improvement of safety designs during the conceptual, design, production and test phases.

3. Mr. G. L. Feazell, Chief, Safety Division, Army Materiel Command, Department of the Army.

a. A number of questions have been asked concerning the status of revisions to the AMC Safety Manual. Our schedule is to have the revised document ready for printing by 30 June, this fiscal year. Revisions will include guidance on criteria for submission of site plans, separation distances for specific ammunition in conveyor line operations, policies involving wall design where walls are required as substitutes for distance, and new data concerning CB weapons.

b. One problem that will be common to each of us will be to keep our standards in line with the DOD Manual, yet provide to contractors specific data involving those hazardous items under the jurisdiction of each of the Services. As I see this situation now, the DOD document will serve as a minimum standard with supplemental requirements imposed by the APRO on an individual contract basis commensurate with the degree of hazard associated with the contract.

c. We must recognize that the explosives safety state-of-the-art is progressing at an ever increasing and diversified rate and no manual is going to keep pace with the technological advances. Therefore, industrial operations and Government manufacturing must move toward the systems safety engineering concepts as a matter of both cost control and accident prevention.

d. The Army's program of systems safety is covered in AR 385-16 and AMC's program is defined together with functions in AMCR 385-23.

4. Mr. Fred X. Hartman, J. F. Kennedy Space Center Safety Office.

a. The discussion covered the Explosives Safety Procedures at Kennedy Space Center, outlining the utilization of documents provided in six volumes, which contained safety operating procedures for all hazardous operations; specifically, those operations involving explosives. The procedure requiring operating personnel to prepare test and checkout procedures for all explosive operations was reviewed.

b. A safety program of this nature requires close coordination and rapport between the Kennedy Space Center Safety Office, the Kennedy Space Center Safety Support contractor, and the safety organization of the contractor involved in the explosives activity.

c. A specific example of an explosive operation conducted in the VAB at the Kennedy Space Center was outlined by showing viewgraphs and explaining the details of the assembly of explosives components to the Apollo/Saturn V Space Vehicle as follows:

(1) Linear Shape Charge Installation
(2) S-1C Retro-Rocket Plume Pattern
(3) S-II Retro-Rocket Plume Pattern
(4) S-II Ullage Rocket Plume Pattern
(5) S-IVB Ullage Rocket Plume Pattern
(6) Launch Escape Motor North-South Plumes
(7) Launch Escape Motor East-West Plumes
(8) Pitch Control and Jetison Motor Plumes
(9) Controlled Area in the VAB for Installation of the Explosive Components

d. The discussion was closed with comments on the utilization of barricades in lieu of security guards and establishing an enforcement program during explosive operations.

5. Mr. Erskine E. Harton, Jr., NASA Headquarters.

a. The NASA approach has been for the NASA Safety Office to provide criteria (the best available) to the field installations. These were not mandatory in the regulatory sense but there was an understanding between the field installation safety offices and the NASA Safety Office that such documents would be considered and appropriately applied.

b. Because of the high degree of autonomity at the field installations, detailed documentation and implementation (as appropriate) were field responsibilities.

c. The DOD Instructions dealing with explosives/propellants manufacture, handling, transportation and storage and the tri-Service

documents on hazards classification procedures, together with the implementing documents of the Services, have served as the basis for NASA's explosives safety program. The ASESB has assisted in explosives safety surveys at field installations.

d. The NASA Safety Office has endeavored to provide interchange between NASA installations of handbooks, manuals and other safety-related documents which had been developed in-house or under contract.

e. Differences did show up, usually because of unique circumstances at a particular center. It was recognized that this might possibly lead to confusion when a contractor did work of a particular type at more than one NASA installation.

f. For such reasons NASA is now undertaking to establish, to the greatest practicable extent, a uniform set of standards, regulations and criteria -- at least a common safety base. I believe that this will amount to some sort of official sanction for those codes, standards and the like which are nationally recognized (e.g., NFPA, ASESB - derived documents). Specialized ones will be promulgated as required.

g. One problem that immediately arises, however, is the definition of standard, criteria and regulation. It seems to me that criteria are the technical background data which are used to produce a specification (a standard) which one can compare another situation against. When the standard or any other criteria become mandatory, it is a regulation.

h. I am convinced that we must strive for uniformity with flexibility enough to give credit for sound safety engineering. Above all, it is essential that somehow criteria are obtained ahead of time through planned hazards/safety research.

i. NASA, in my opinion, probably will not in the foreseeable future have all mandatory standards, but will officially adopt those where there is a common denomination in-house and will continue to work with other Government organizations and private industry toward that same end -- uniformity.

j. It is planned to inventory our explosives/propellants and devices containing them with the intent to eventually institute minimum test procedures for hazards classification, also, derivation of a satisfactory identification/coding system is intended.

6. Mr. Herbert M. Roylance, Director, Safety Division, Naval Ordnance Systems Command, Department of the Navy.

a. As with the Army and Air Force, who have previously spoken, the Navy's regulatory safety documents are in need of revision to bring them up-to-date with present weapon technology and the rapidly changing regulations concerned with weapons safety. One interesting problem that the Navy faces, in consideration of Don Endsley's comments concerning safety problems on the flight line, is that we also have the same problems ashore and on aircraft carrier flight decks. In addition, we have the Army's problems in the field with Marine ground drops and added to all this, we have a great variety of shipboard explosive safety problems.

b. In order to provide proper safety coverage, we have two series of manuals, one covering the forces afloat, this is Ordnance Pamphlet 4 which comes in two volumes; one being primary instructions and the second, regulatory. These cover all shipboard aspects of explosive safety. For activities ashore, OP 5 is the basic document, Volume 1 of which contains all the basic safety regulations including all the quantity-distance tables. Volume 2 covers production and processing of ammunition and explosives, and Volume 3 provides guidance for storage at advanced bases and forward areas. It contains a somewhat relaxed set of safety regulations, but provides we feel, adequate safety under the conditions encountered in these areas.

c. Still another specialized field of explosives safety is that of transportation. These regulations are contained in OP 2165.

TRAINING OF EXPLOSIVES OPERATORS AND HANDLING PERSONNEL

Moderator: E. I. Ross
AMC Ammunition School
Savanna Army Depot
Savanna, Illinois

TRAINING OF EXPLOSIVES OPERATORS AND HANDLING PERSONNEL

SUMMARY

Resource Personnel:

Mr. W. E. Carper, Naval Ammunition Depot, Crane, Indiana
LTC B. J. Doctor, Lowry Air Force Base, Colorado
Mr. T. L. Lacopo, Joliet Army Ammunition Plant, Joliet, Illinois
Mr. Charles Valesh, Badger Army Ammunition Plant, Baraboo, Wisconsin

Objective: Exchange of ideas on the type of training programs conducted for explosives operators and handling personnel to highlight content, methods and techniques that contribute to an effective program.

Approach:

1. The four resource persons listed above were specifically selected to represent the Army, Navy and Air Force in this subject. In addition, these persons were selected to represent contractor plants having a centralized training establishment and a decentralized training program. Another consideration was to have a formal school representative discuss the subject training from his point of view. Finally, four depots were surveyed in order to present an overview of the way they fulfill their training requirements.

2. Each of the designated representatives gave a short review of their particular training mission by generally highlighting training problems, organizational structures, new ideas and instructional material content.

3. While these individuals spoke, audience participation through questions or comments was solicited.

Discussion:

1. The major areas of discussion generated through the audience participation centered on:

   a. How do you evaluate training?
   b. Should training be conducted by a central training agency or by each line foreman or supervisor?

2. Other points discussed included:

   a. What is the proper mixture of attitude training and technical training?
   b. Should supervisors conducting their own training programs be given a short instructor training program?
   c. How much and when is follow-up training needed?

Results:

1. Participants asked for the availability of specific school courses to meet their needs - Courses and Schools were identified.

2. Participants asked for certain films, instructional materials, slides and transparencies - Locations of materials were identified.

3. Group discussion provided various reasons for having centralized or decentralized training. The advantages and limitations of each were highlighted. A handout was provided to present the requirements for successful accomplishment of each type. The actual selection of one type over the other was not made. This judgment to be made under each set of circumstances presented by the activity involved.

4. Various ideas were suggested regarding forms used in the evaluation and certification of training. Proper records and close supervisory observations provide insight into follow-up training needs.

5. Heavy emphasis was placed upon the need to recognize that lack of training is only one of many contributors to accident/incidents. Supervisory laxity, equipment design, attitude of worker, and excessively fast production requirements also contribute.

6. Participants generally agreed that supervisors should be provided some form of instructor training to include effective communications, lesson and course design, use of training aids, and supervision and evaluation of training.

7. Training aids used in safety training seem to be more effective if they are cartoon oriented instead of straight words or narration.

BLANK PAGE

AIR TRAINING COMMAND SAFETY TRAINING

by

LTC B. J. Doctor, USAF
Technical Training Center
Lowry Air Force Base, Colorado

Effective 1 October 1967, ATC consolidated all safety courses (Explosive, Missile, Ground, and Nuclear) at one base and established the Safety Training Branch, under the Department of Aerospace Munitions Training at Lowry AFB, Colorado. The Branch has an authorized faculty of 31 instructors and trained nearly 1,000 students during FY 1968. Based on present flow charts, approximately 1,350 students will receive safety training during FY 1969.

Explosives Safety is not only closely related to each of the other safety courses, but also to 34 other resident munitions courses conducted at Lowry AFB. Explosives safety constitutes a major portion of any munitions course being conducted.

Explosive Safety

One of the roles of Air Training Command is to qualify personnel from various commands to perform the duty as non-nuclear Explosive Safety Officers or Technicians. This training, conducted at Lowry Air Force Base, is the highest level of explosive safety training in the Air Force and is monitored for scope, content, accuracy, and currency at Hq USAF by the Office of the Deputy Inspector General (DIG). The course objective is to impart an understanding of the minimum explosive safety criteria established by DIG Safety and contained in various Air Force regulations, manuals, and technical orders. The word "minimum" is emphasized. Every major command has its own unique mission requirements and, therefore, will supplement the basic manuals and regulations or create their own regulations, manuals, etc.

These additional instructions must never degrade the minimum criteria established by DIG but rather enhance these criteria. These additional safety criteria would be covered by the various commands in their own training program which they are required to conduct.

The explosive safety training being conducted at Lowry Technical Training Center currently consists of two courses: an officer and enlisted course, both three weeks long (90 hrs). An eighteen week, advanced officers explosive safety course is presently being developed with a scheduled starting date of January 1969. Originally, the three week courses were established to train personnel serving as Ground Safety Specialists, inexperienced in explosive safety to fulfill their responsibilities as Explosive Safety Officers or Technicians. This source constituted the initial student input to the courses; however, in the interim, students from the following areas have attended: Defense Contract Administration Region personnel (DECASR), Air Force Plant Representatives (AFPRO), Transportation Specialists, Munition Specialists (463XOs), EOD Specialists (464XOs), Weapons Mechanics (462XOs), Nuclear Weapon Specialists (463XOs), and Munition Officers, both 4625As and 4625Bs. All areas in the field of conventional munitions are covered in the course: manufacture, procurement, transportation, storage and handling, and loading on aircraft. Officers thru the grade of Lieutenant Colonel, enlisted thru the grade of CMSgt, and civilians thru grade of GS-14 have undergone training.

In addition to the courses which are taught in residence at Lowry, the School maintains a capability to deploy a team of qualified instructors with required training materials to teach explosive safety elsewhere

within the ZI or overseas. Last year at PACAFs request, this instruction was given to 71 officers and enlisted stationed in SEA and other Far East installations. Presently, a team is conducting this training at Itazuke AB, Japan, for a similar number of students from PACAF Command. Due to the constant changes of personnel in the combat environment, it appears that this training at forward bases will be a recurring requirement. This demonstrates the concern and action taken to get this knowledge to the personnel in the operational areas where it is sorely needed. It is anticipated that requests from other overseas commands may be received for like support.

With the vastly increased inventory of conventional munitions since circa 1962, explosive accidents and incidents have increased, revealing the need for associated explosive safety training. The previously mentioned courses not only cover the responsibilities of the Safety Officer and Safety Technician job description requirements, but, also, and equally important, instill and develop an attitude of safety consciousness in the individuals undergoing training.

Through published Air Force directives, students are given an understanding of explosives safety as a staff function and its responsibilities to the commanders and subordinate units. They are further impressed with the requirement for the construction of an Explosives Accident Prevention Plan to provide for "before the fact" actions. "Post mortem" safety, which stresses corrective actions after an accident has occurred, is unsatisfactory unless all possible prevention measures were taken before the accident. Two significant areas of our training program are worthy of identification and some discussion:

First: A complete library of reference material; Air Force

directives, Technical Orders, and DOD publications is made available to the students. Problems of handling, storage, loading, etc, of various munitions items are presented to the student to be resolved.

Second: Students are divided into teams of three to four people and given a base site planning problem to resolve. The basic outline of a base plan, showing runways, taxi lanes, flight line, buildings, base shops, radar and radio locations, perimeter fences and gates and other permanent features of the base is given the student team. Along with the above, a list of items representing the base mission is given the team; numbers of aircraft, by type; and a complete arsenal of munitions, bombs, missiles, squibs, all by type and quantity to include chemical, biological and non-nuclear warheads. The student team is then charged with siting all functions necessary on the airdrome; alert aircraft, hot pads, loading areas, storage, security, etc. When considered necessary, waivers may be included. Upon completion, each team briefs the school faculty on their site planning problem showing locations, distances, quantities, barricades, etc. The students are, in turn, critiqued by the instructors on how well the problem was accomplished.

A major problem associated with this specialty is that explosive safety has been accomplished on an additional duty basis since an AFSC has not been specifically designated for this function. Currently, the explosive safety responsibilities are included in the job description for the Ground Safety Officer or Technician, AFSCs 1935 and 241X0, respectively. When the explosive safety position is filled as an additional duty, experience gained by the incumbents in these positions is lost when they return to their primary duty area. This condition has contributed to the current

plans for awarding a separate AFSC for this function. The recognized need and recommendation for a separate specialty identification of explosive safety personnel was made in a staff study prepared by the Deputy Inspector General for safety. Their findings disclosed that a shortage of Air Force qualified personnel, equivalent to the Army's Ammunition Inspector, exists. Some 250 staff positions have been identified which cannot be filled adequately when vacancies occur. To offset this shortage of qualified personnel, ATC has been directed, and is currently developing, a comprehensive technical course of instruction to parallel, in part, the training given by the Army in its Ammunition Inspector Course. Recently, Hq USAF approved a separate AFSC, 1961, (Explosive Safety Officer) and has written a job description covering the specialty. (See Change U, AFM 36-1, dated 31 July 1968) In response to command staffing of the proposed course content, ATC has developed the basic outline for the Advanced Explosive Safety Course, incorporating the command recommendations and suggestions for changes. At a training coordination conference held in October 1967, attended by representatives of the various commands, the basic course outline, with minor changes, were approved. Present indications are that the course will be 18 weeks in length (540 hrs).

It becomes increasingly evident that command interest, support, and emphasis are the prime ingredients to the creation of a safe explosive operation. Only by recognizing and fulfilling his delegated responsibilities, can the commander expect to preserve essential combat resources entrusted to him, thereby assuring that the USAF maintains a position of maximum readiness consistent with an environment of adequate safety.

The explosive safety training at Lowry Air Force Base will produce qualified personnel capable of advising the commander, enabling the fulfillment of his mission responsibilities.

JOLIET ARMY AMMUNITION PLANT TRAINING PROGRAMS

by

T. L. Lacopo
Joliet Army Ammunition Plant
Joliet, Illinois

A. Joliet Army Ammunition Plant Training Programs:

1. New Hire Orientation

   Basically a two and ½ eight hour day classroom orientation covering history of the company and Joliet Army Ammunition Plant, company benefits, munitions produced at JAAP, safety with munitions, kinds of explosives, explosive's use, job classification, how they are treated by company and what they are expected to do, followed by a 50 question exam.

2. 3A Training

   A full 8 hour day of BLU and CBU orientation, group layout and jobs occurring within completed by a 50-question exam with a passing grade of eighty.

   <u>3A Index</u>

   - Introduction to 3A
   - Review of general explosive information
   - Explosives used in 3A
   - Concept of anti-personnel weapons
   - Introduction to BLU
   - Physical characteristics of BLU
   - Breakdown and explanation of BLU components
   - Introduction to SUU dispenser
   - Introduction to CBU
   - Delivery to target
   - Functioning of fuze contained in the BLU

Functioning of bomb

Loading, assembling and packing

ADU

Brief review of material covered

Fifty question test

Visual aids employed

Classroom material provided for note taking

3. O.J.T. Training Manual

Our O.J.T. manual is the trainer's guide to making a more efficient and safety conscious worker. This manual covers:

The trainer

When a worker is assigned to you

The trainer's attitude

The Learner

Readiness

Concentration

Repetition

Habit

Memory

Effect

The Material

Make a job breakdown

Prepare a timetable

Have all material ready

Have work place properly arranged

The Method

Preparation

Presentation

Application

Follow-up

Training Period

Time involved

Plan the job

Promotion canvas

How to implement

Example

Waiver JAAP 2511

Completion of form

Example

Skills inventory

Timetable

Training statements

How to implement

Example

Job Title and Description

Group 1

Group 2

Group 3

Group 3A

Suggestion system

Employees suggestion

Investigator duties

Example

Tour of operating Group

4. Special Courses

a. FLO program covers training a worker in the following:

Selecting the operator.

Program outline of forklift training to be presented in the classroom.

Program outline of forklift training program to be presented (practice area).

Checkout procedure before starting gas engine forklifts.

Checkout procedure after starting gas engine forklifts.

Operation of forklift truck controls.

Elementary driving.

Load capacity of lift truck.

Materials handling - palletised.

Freight car loading and unloading.

Safety rules and regulations forklift operators.

b. Drivers Education

Complete instruction on plant regulations with driver's test, eye and reaction test, and Government Driver's lisence.

c. FTO Program

Special course developed for an efficient training of our men in lawn and grass mowing.

d. Safety lecture-foreman

Course given for indoctrination of foreman as to stress safety on the line and what to do if people don't obey it.

e. Supervision Training

5 day course for all new foreman and supervisors so he will know how to handle and beware of any problems that may occur on the production line.

f. Z-D Session

Zero Defects sessions organizations and composition given by Production Training. Also organization of E.C.I. program.

g. I & D Programs

Text prepared and coordinated for line foreman by Production Training. With this program questions of wage personnel are answered promptly and effectively for the betterment of the wage personnel and supervision.

B. Program Development:

1. Organization

A. Training Staff

Show organizational chart explaining and showing duties of each. What they pertain to.

2. Training Program Development

A. Need of program

Originates when - example: An accident occurs, in another plant which or could happen at Joliet, or need arises because of a general test given, poor production, poor efficiency, request from other department heads or a near miss accident at our own plant.

B. New Government specification exam. 4 way pallet.

3. Training Follow-up

A. Daily follow up by training personnel example: (show skills inventory sheet). With this sheet, the on the job trainer keeps a continous record of training of the employee.

B. At time to time a special test will be given on highly skilled job, example: CSO operator - Group 3A.

C. Training statement.

C. Problems:

1. Absenteeism is one of the largest problems and we continuously try to reduce it by having employee contacts with these people, giving awards for attendance, and giving promotions to the people who attend regularly.

2. <u>Termination and LOA</u> - Since our plant is located in a heavily industrialised area, many of our present and past employees (mainly women) only work for a particular object, pay off medical bill, new color TV, etc. and then quit or go on a Leave Of Absence keeping their seniority.

D. Equipment

1. 16mm camera and sound projector: Used in documentation of work in Groups also filming of explosive demonstration. Exampel: 105mm cartridge case with propellant bag exploding.
2. 35mm slide camera and carousel projector: Used in filming specific jobs into classroom from group. Eliminate of speaking time of instructors.
3. Overhead projector and Vim pack: People's attention kept by showing a screen while the instructor is talking about it. With a great use of color in these charts, the pupil enjoys what he is watching.
4. Prepared films: When an excellant film is found on safety or general interest we incorporate this into our training program. Also seasonal films are used such as: pertaining to winter driving. From time to time, we use big picture film prepared by the U.S. Army.
5. Programmed text: By now these have been passed out and people have a chance to look at them.
6. Television (closed circuit T.V. system).

E. Safety Programs:

1. Never ending training program which occurs from the first date of hire to their day of termination at the plant. In these programs such things as use of clothing, reason for change of rules, seasonal safety, of the plant safety, are stressed heavily.

2. Foreman Safety Training Program -
Special course given when foreman needed a refresher in safety and general policies of Uniroyal and Joliet Army Ammunition Plant.

3. First Aid Training.

4. Fire Extinguisher Explanation.

5. 5 Minute Daily Safety Meeting in Group .
30 Minute Monthly Meeting.

F. Program Organization:

1. Composed and given to meet the mentality of people, with feed-back in classes required and requested. With feed-back the instructor is more able to fully explain the material the students do not comprehend. Classes have programmed text, so that any of my men can fill in for each other.

G. O.J.T. Training

With good basic understanding of our product received from orientation classes the new employee is turned over

to hands of the on the job trainer. Here the employee learns, works and handles the real product. From this point and until his termination the employee is continually under the eye of the on the job trainer from his relatively simple starting, job and all future promotic

All instruction with our employee in the group is in a simple person to person basis.

Special back to class training.

If a large number of people have to be trained on a certain subject; Example: new fuze, new product may be pulled back into the classroom for special instruction, or start of ADU line in Group 3A.

Training at JAAP is not seen as just a way to start the new hire but a way to improve the wage employee and ourselves in turn producing a better and higher quality product. The training staff is always on the alert to find new ideas to incorporate into our training program as well as ways to improve production, stress safety, increase efficiency and to support our fighting men in Viet Nam.

ELECTROSTATIC HAZARDS IN PROCESSING EXPLOSIVES

Moderator: J. T. Petrick
Naval Weapons Laboratory
Dahlgren, Virginia

ELECTROSTATIC HAZARDS IN PROCESSING EXPLOSIVES

SUMMARY

Topics discussed were as follows:

a. Use of stainless steel fibers in textiles for electrostatic safety,

b. Use of transparent, inherently anti-static, plastic films for explosive containers,

c. Charging phenomena of powders,

d. Proposed methods for determining the electrostatic sensitivity of explosives,

e. Problems encountered with use of various electrostatic potential measuring instruments on insulating surfaces, and

f. The charging of carbon dioxide fire extinguishers during use.

The general result of the sessions was the agreement that standard methods must be devised for evaluating anti-static materials and treatments, and for determining the sensitivity of explosives and electroexplosive devices.

NOTE: During the second specialist session, questions arose concerning the electrostatic spark hazard produced when purging fuel tanks using a carbon dioxide fire extinguisher.

The Missile Safety Research Branch, NWL Dahlgren, Va. conducted simple experiments to determine the magnitude of this problem. The results of the experiments indicate that the extinguisher receives electrostatic potentials as high as 5,000 volts during a one-second operation. This corresponds to an energy of 0.225 millijoules, which exceeds the ignition energy of the diethyl ether-air mixture reported in footnote (1). The experiments also indicated that after several operations the extinguisher no longer produced solid carbon dioxide particles and thereafter no more than a few hundred volts were recorded.

In addition to the experiments, a literature search was conducted that yielded the following information:

a. Footnote (2) Vol 1, 327-28, para 322

"In air purging....all precautions shall be taken to insure that the apparatus used to inject the air is bonded to the container in order to minimize the hazard of ignition by static electricity."

b. Footnote (2) Vol 1, 327-29, para 334

"When using liquid carbon dioxide (for inerting of vapor space), it is essential that the gas be released at such a rate that no solid carbon dioxide will be discharged since solid particles may generate static electricity."

In view of the above this hazard may be mitigated by electrical bonding of the carbon dioxide extinguisher to the tank being purged; the person using the extinguisher; and the floor, if conductive. Additional measures must be taken to restrict the flow rate of carbon dioxide thereby preventing the formation of solid carbon dioxide particles.

Further information can be obtained by contacting the National Board of Fire Underwriters, American Insurance Association, 110 William St., New York, N. Y. 10038.

(1) Crugnola & Robinson, Measuring and Predicting the Generation of Static Electricity in Military Clothing, Headquarters Quartermaster Research and Engineering Command, U.S. Army, Natick, Mass. Sep 1959 pg. 7

(2) National Fire Codes, National Fire Protection Association, 60 Batterymarch St., Boston, Mass., 1966

DEVELOPMENT OF SAFE CLOTHING FOR USE IN EXPLOSIVES PREPARATION AREAS

by

Robert E. Thompson
Brunswick Corporation
Needham, Massachusetts

I am sure that everyone has at one time or another experienced the annoyance and discomfort of electrostatic discharge. This is usually most prevalent during the cold, dry, winter months, and you may have discovered this static discharge from walking on carpeting and touching a metal doorknob or other suitable ground. It is also noticeable with the removal of clothing and is a definite nuisance to many people upon entering or leaving an automobile. In most instances, this static discharge is an annoyance and a discomfort to the individual, but it seldom goes beyond that.

This article concerns the potential hazards of static electricity as related to textiles that encompass the field of clothing, uniforms, filter bags, and others.

The most obvious danger of static discharge from a human being is the energy contained in the spark and its ability to detonate explosives, dust laden atmospheres, and gas and air mixtures of various types. The second area of inherent danger involved with this static spark discharge is the involuntary reflex action which people undergo when experiencing the discharge from their body to ground. This can cause the individual to move quickly, which in some instances could bring him in contact with dangerous machinery or perhaps even cause him to drop volatile materials.

The Brunswick Corporation has for the past several years been engaged in the manufacture and application of very small stainless steel fibers manufactured under the trade name of BRUNSMET®. One of the large end-uses for this fiber is in the control of static electricity in various textile structures. BRUNSMET® metal fibers are available in many different materials such as tantalum, niobium, and nickel base super-alloy, but this article will be confined to the 304-type stainless steel fiber. Brunswick is currently producing these fibers in 8μ, 12μ, and 25μ diameters in continuous filament, staple, and tow and is developing 4μ, 2μ, and 1.5μ.

Organic textile fibers can be made highly conductive by the inclusion of a small amount of BRUNSMET® blended with them. This is done on conventional textile equipment in all systems such as cotton, woolen, and worsted and is currently enjoying wide use in many fields, such as

anti-static carpeting. In this blended yarn form, BRUNSMET® becomes a permanent part of the woven or knitted structure and is unaffected by laundering, heat, light, and most of the ordinary chemicals with which it would come in contact. As an integral part of the textile structure, its conductivity is not dependent upon the amount of moisture available in the air and therefore functions in relative humidities as low as 0%. Indeed some of our experiments have been carried out at relative humidities approaching this figure.

Laboratory tests performed at the Brunswick labs in Needham, Mass., are usually carried out under the controlled conditions of 15% R.H. and 70°F. This low R.H. figure was decided upon after measuring the R.H. in various heated buildings in the area during cold, dry days. In most instances it was found, unless some sort of humdification was supplied to the building, that this 15% R.H. was a realistic one. Tests under these conditions on various materials such as nylon, polyester, cotton, and polyester/cotton blends have produced remarkable results.

The two most widely known and widely recognized methods of testing for static electricity are the cling test, AATCC 115-1965T, and the resistivity test, AATCC 76-1964. While the cling test is useful in ascertaining that there is static buildup in a textile material, it is difficult to determine the quantity of such static charge. The resistivity test measures surface resistance in textile materials to an electrical charge. This is useful in determining whether a given textile fiber is a good or poor conductor of electricity and to what degree.

Our test for resistance is set up on a 4" spacing and the resistance is measured across this distance. Utilizing this method, we have found that the resistivity of most of the synthetics and polyester/cotton blends were so high that reading them became a matter of guesswork. While cotton is known to be a low producer of static electricity, its resistivity at 15% R.H. was on the magnitude of 2.5×10^{12} ohms per sq. Resistivity tests performed on uniform material containing 80% polyester, 19% cotton, and 1% BRUNSMET® stainless steel were in the order of 1×10^{8} ohms per sq. As can readily be seen by this, the inclusion of a very small amount of stainless steel fiber to existing organic fibers results in a much more conductive fabric.

Further testing was carried out by measuring the rate of decay on textile materials after an electrical charge had been introduced. This was accomplished by introducing a 6,000 volt charge across the fabric and then measuring the length of time for the complete decay of that charge. In all instances under these low humidity conditions, both the synthetics, cottons, and cotton/synthetic blends had an extremely low rate of decay. The rate of decay on uniform material containing steel was almost instantaneous indicating a rapid release or dissipation of potential charge.

Installation of filter bags in the chemical field have shown that a small amount of steel eliminates or greatly reduces the potential of electrostatic discharge in areas where airborne particles could constitute a definite hazard. In one particular instance, a 3% blend of steel in the filling direction of the bag was sufficient to bring the static discharge from 20,000 volts down to less than 1,000 volts.

It is a well known fact that in many areas synthetic materials are not allowed due to the potential hazard of static discharge. This is unfortunate because uniforms and lab coats as well as other materials constructed from synthetics have advantages over cotton in many instances, due to their chemical resistance, ease of cleaning, resistance to dirt, and long wear life. Our tests have shown that the inclusion of a small amount of BRUNSMET® can usually render synthetics less static prone than cotton regardless of what the humidity might be. The ordinary organic type anti-stats which are currently available work on the theory of the absorption of moisture from the air. It therefore necessitates that this moisture be available. As the relative humidity decreases, these anti-stats tend to loose their efficiency. This is unfortunate because it is at these low relative humdities that static becomes most prevalent. Also these organic antistats have to be added during each washing of the material while BRUNSMET® stainless steel becomes an integral part of the fabric and as such will last the life of the fabric. Independent studies have shown that a person coming into a heated room on a cold, dry day and removing outer clothing made from synthetics can generate a potential in excess of 8,000 volts while the same material containing BRUNSMET® generates a negligible charge. Assuming a maximum capacitance of 300 micro-micro farads for the human body, the energy potential would be 9.6 milijoules at 8,000 volts. Of course various aspects come into play such as conductive shoes and conductive flooring but still a potential hazard does exist.

BLANK PAGE

Static-dissipating plastic films for the space age

by
DAN C. ANDERSON
The Richmond Corporation
Redlands, California

INTRODUCTION

Since Marconi's day the word "static" has been associated with objectionable interference with electronic transmission. As the electronics industries have expanded to their present technological level, static-discharges have become more and more troublesome, in rather unexpected ways, so that the relatively simple but misunderstood phenomenon of static is now a major "bug" in a sophisticated science.

For example, at the Jet Propulsion Laboratories in Pasadena, a clear vinyl plastic curtain surrounding the portable downflow clean room in which the Mariner spacecraft was assembled had to be replaced with an antistatic polyethylene curtain, because technicians brushing the vinyl curtain in passing generated static charges which interfered markedly with electronic checkout of the spacecraft's delicate instrumentation.

In 1964 static generated by the adjustment of a polyethylene drape over a solid-propellant rocket on a spin test stand at the Eastern Test Range set off the electroexplosive igniter squib, firing the rocket inside the laboratory and causing the deaths of three technicians. The accident, recreated in a study by Cornell Aeronautical Laboratory, served to focus the attention of the entire aerospace industry on the hazards of static, and to encourage the development of static-safe packaging materials and methods for EED's (electroexplosive devices). Many of these techniques are now being adapted to general packaging of other static-sensitive electronic components.

One of the more expensive lessons being learned by the industry is the vulnerability of field-effect transistors to "puncture" by electrostatic discharge of the high voltage generated by common packaging materials such as polyethylene, in addition to the more familiar static discharge from personnel who handle or assemble these devices.

In precision packaging materials used in clean room areas, the attraction of dust or airborne contaminants to the ultracleaned surfaces of special bagging and wrapping materials is being minimized by the use of special antistatic polyethylene and nylon films.

However, the search for static-safe packaging materials and methods has been severely hampered by a lack of generally accepted or standardized specifications and test methods for determining the degree of anti-staticity possessed by the various synthetic packaging materials presently available. Many of the concepts and tests applied in the past were designed before the development of present day plastics, and do not effectively cover the problem from the point of view of today's technology.

Front view of the white room pre-entrance to the A2 level of the Vertical Assembly Building (VAB) Cape Kennedy. The space craft itself is shown to the left of the picture.

Transparent anti-static nylon dust cover is fitted to the command and service modules of the Apollo space craft prior to mounting on the Saturn V

STATIC GENERATION AND DISSIPATION THEORY

To clarify the problems somewhat, let us briefly review how static electricity is generated and how it may safely be dissipated from packaging materials. Whenever two surfaces, whether liquid or solid, come into contact no matter how gently, their surfaces are crushed on the atomic level and electrons pass back and forth between the objects. On seperation, one surface always comes away electron-rich (negatively charged) while the other is electron-poor and has a positive charge. Friction or rubbing is not necessary for this charging to take place, mere contact and seperation are enough. Rubbing merely increases the number and frequency of contact-seperation incidents, each of which causes local electrification. The degree and polarity of the imparted charges depend to some degree on the relative position of the materials in the triboelectric series. Static charges, being all of the same polarity on an object, repel one another and therefore accumulate on the outermost surfaces of the charged object. If a conductive coating, no matter how minuscule, be present on the surface of an item, the charge will spread over the entire surface, so that a grounding touch at any point can bleed off the whole charge. The conductivity of this surface layer may be very small, provided it is contiguous, because while high voltages are common in static phenomena, amperages are almost immeasurably low.

Therefore it is not the amperage of static which concerns us, but rather the possibility of a high voltage spark. A spark produces locally intense heat, locally intense light, a small shock wave and an electromagnetic field, any or all of which can be damaging to certain electronic devices. Static sparks can and have been known to detonate electro-explosive devices or ignite flammable solvents or anaesthetic mixtures. Even

the uncontrollable galvanic reflex which makes a person "jump" when he receives a static jolt can be dangerous in certain critical areas. Bag, drape and wrap materials should be developed and selected with two points in mind. First, to prevent the electrostatic charging of the materials by rubbing against themselves or other materials. Second, if charging must occur, to provide means of safely dissipating the charges to ground *without the production of a spark* when the ground connection is established.

The only other method for removing a static charge involves bleeding the charge off through the air surrounding the object, if that air is made sufficiently conductive by ionization. Ionizing air is the only practical manner of increasing its conductivity and may be accomplished by the use of flame, infrared heaters, certain wave lengths of ultraviolet light, x-rays, sharp points (charged or uncharged) and placed near the film or object to be destaticized, or radioactive sources such as Polonium 210. Locally effective though this method is, it does not produce a lasting effect on a film or object which may be re-charged by contact immediately after it leaves the ionized atmosphere.

APPROACHES TO STATIC-SAFE FILMS

For field use or general packaging work therefore it becomes necessary to build "groundability" into the packaging films themselves, so that the safety feature goes with the film throughout its life wherever it is used. Several approaches to this goal have been proposed and studied by research and industry. Some of the most promosing are listed as follows.

Laminations of Films to Foil

The idea that aluminum foil, laminated to a packaging film such as poly-ethylene might be a good groundable combination is negated by the fact that the ordinary polyethylene surface is non-conductive. Therefore, when a bag is made by sealing the polyethylene sides of two sheets together, a rather efficient capacitor has been constructed. In many common military barrier laminations such as scrim foil polyethylene combinations meeting the requirements of MIL B 131, a layer of foil is buried between non conducting materials so that the whole laminate is ungroundable.

Use of Aluminum Foil Alone

Excellent bleed-off of static charges can be achieved by using metal foil alone but several drawbacks exist. To be effectively conductive foil must not be coated with non conductive sealing surfaces nor laminated to non-conductive films. This severely limits its physical strength and rules out the hermetic heat-sealability so desirable in most packaging applications. Morever, the opacity of foil precludes examination or inspection of packaged items, while flexure and abrasion produce not only holes in foil but quantities of metallic particles, each of which represents a potential "dead short" in electronic devices. The very contact of raw foil with the dissimilar metal of a packaged item can result in electrolytic corrosion.

Vacuum Metallized Films

Thin deposits of vaporized metal, usually aluminum, may be deposited on the surface of a previously out-gassed film held or moving past over molten metal in a large vacuum chamber. Good surface conductivity may be achieved on one or both sides of a film by this means, but the surfaces are not interconnected, so that the capacitor question arises once more. If such coatings are abraded, electrical gaps may be created because the coatings are not self-renewing. These materials, moreover, are generally opaque or at best a cloudy grey. Printing films with conductive inks generally produces a material with the same disadvantages, and in both cases heat-sealing tends to destroy such coatings, even if the coating permits heat-sealing to take place.

Conductive Surface Sprays or Coatings

The textile industry, long concerned with the "drape" or "hang" of garments and such problems as eliminating the shock effect from upholstery, seat covers and carpets, has resorted to the use of anti-static sprays or surface coatings. Applied to films, however, most such coatings are invisible and not self-renewing, and tend to prevent heat-sealing. If reapplied frequently to finished objects, they can and do prove effective in giving groundability to otherwise non-conductive items. It should however, be borne in mind that a section cut from a sheet of plastic so rendered conductive on both sides has no interconnection between the surfaces — the capacitor again.

Impregnation of Films With Conductive Granules

It is possible in the extrusion of polyethylene and similar thermo-plastics to incorporate in the resin mix finely divided conductive pigments or granules which render the film conductive throughout if a sufficiently high percentage of such additive be present. Such materials are truly conductive, not merely surface conductive and are commonly used for grounding straps, shoe covers, table tops and conductive flooring in static hazard areas. In thin gauges however the physical strength of these plastics is diminished markedly by the pigmentation. Such materials tend to slough particles of carbon or conductive plastic when flexed or abraded, and are therefore unacceptable for clean room or precision packaging work. Because the entire volume of the film is conductive, surface resistivity cannot be checked by methods designed for measuring the surface conductivities of *insulating* films, therefore a direct comparison with values determined for films rendered surface-conductive by other means is difficult. The opaque nature of these films presents further problems.

Internal Organic Antistatic Agents

Organic antistats such as quaternary amines and similar agents may be introduced to plastic resin blends prior to extrusion, effectively and permanently destaticizing the extruded film. Indeed, this technique has long been applied to blow-molded polyethylene bottles to prevent the attraction of dust to their surfaces. One such antistatic packaging film is offered by The Richmond Corporation, and called RC AS-1200. This transparent polyethylene film is identified by a pink coloration, and offers excellent bleed-off of static charges when touched or grounded, while its other properties remain those of any high quality polyethylene film.

The mechanism of static bleed-off in RC AS-1200 is based on the attraction of humidity to the surface of the film where it combines with the antistat agent to form the microscopic conductive layer necessary to drain off any charge. Should this layer be abraded away, it reforms at once, so that the material retains antistatic properties throughout its life. More recently, The Richmond Corporation adapted a similar technique to the production of an antistatic nylon film called RC AS-2400, selected as the material to form a transparent dust cover over the Command and Service modules of the Apollo spacecraft at Cape Kennedy. Here antistatic polyethylenes were ruled out because of flammability considerations, in favor of the self-extinguishing nylon film.

ORGANIC ANTISTAT BEHAVIOR

The use of internal organic antistats to produce static-safe packaging materials is the latest and least expensive of the techniques described. To understand why and how the process works, let us examine the role of moisture in static dissipation.

Almost everyone has experienced the shocking effect of touching metal or another person after walking over a new nylon carpet on a cold, dry day. The crackling spark which equalizes the difference in potential can be clearly seen, heard and felt. Two brief lessons can be learned from this simple experience

First one cannot shock himself say hand to hand or hand to nose, because the miniscule perspiration layer on the surface of the body spreads the charge relatively evenly over one's surface. Second the phenomenon is rarely observed during the summer or at times of higher relative humidity because moisture condensed on the rug's surface renders it sufficiently surface conductive to minimize charging.

Lewis Walkup of Battelle Institute has stated other things can affect the electrical conductivity of objects, but none is so important as moisture in or on the object itself. Surface moisture is nature's best antistat, but may be improved upon and rendered more effective.

At low humidity levels, moisture droplets on surfaces are small and unconnected; at higher relative humidities they are larger and more numerous and contact one another. The use of detergent-like or surfactant organic additives, commonly called antistats, serves to break surface tension and connect these small droplets into a single layer which contains some ionized antistat. Thus the coating remains effectively static-conductive at very low relative humidities. The impregnated resin from which the film was made holds a supply of antistat available to the surface layer when needed. The very small percentages of antistat required to produce the effect makes possible films whose other properties are affected only slightly or not at all. While such antistats must be hydrophilic or water-soluble to be effective, impregnation of a plastic with a properly chosen antistat can be done so that surface humidity can never extract all of it in a normal lifetime. Therefore, unless such film be boiled, laundered to excess or given long outdoor exposure to rain and ultraviolet light, the treatment remains effective as long as the plastic exists. When used outdoors such antistatic bags or drapes are usually covered by heavy duty barriers, while the inner antistatic bag or wrap acts as a kind of Faraday cage around the contained device, and is grounded before and during removal.

This principle is set forth in National Aerospace Standard No. NAS 3425 revision 1 dated 30 September 1967, prepared by the Aerospace Industries Association of America. The standard entitled "Bag, Anti-Static Single Item", reads in part: "The bag shall be fabricated of a minimum 4 mil anti-static resin mix and shall have a maximum surface resistivity of 1×10^{12} ohms when tested per ASTM D257-61."

Similar wording is used in SAMSO Exhibit 69-9, entitled "Packaging and Packing for Space and Missile Systems" published by the Department of the Air Force Space and Missile Systems organization.

EVALUATING ANTI-STATIC BEHAVIOR

Countless methods for measuring antistatic behavior exist, ranging from the old pith-ball method familiar to high school students through the "quick and dirty" test in which a wool stroked sheet of plastic is held one inch above an ash tray. In the latter test, a charge of approximately 4000 volts will pick up cigarette ashes from an inch away.

Direct quantitative measurement of static charges on the surfaces of materials without direct contact is made possible by such instruments as the Model CMI-7777 static meter, a pistol-shaped hand-held device available from Custom Materials Inc. The meter is held at a distance of 1, 6 or 12 in. from a charged surface and indicates the polarity and degree of the charge in kilovolts. The instrument retails for about $295 with carrying case.

A similar but less sophisticated static meter is the Model M-1001, available through Scientific Enterprises, Inc., Bloomfield, Colorado. This is a black crackle-finished meter box about 4 x 4 x 2 in. with a removable handle, and reads static charges up to 8000 volts at 6 or 12-in ranges. It retails for about $150.

Such devices furnish actual readings of static charges and are far more useful in determining the anti-static behavior of films under conditions of actual use than are such methods as surface resistivity or conductivity tests, because such tests employ currents vastly larger and of longer duration than those encountered in static. Such currents can "boil off" the conductive moisture-plus antistat layer used in antistat films, and produce artifically high readings not truly indicative of groundability.

A far more accurate test method has been developed at the Naval Air Development Center, Johnsville, Warminster, Pennsylvania, by the Aero Materials Department's Irving H. Custis. The electrostatic test assembly employs a high voltage supply and tests a 3 x 5-in. sample foil, film or laminate by charging it with 5000 volts, either positive or negative (usually both in succession) and grounding the specimen. Time required to charge and the speed of the bleed-off of the charge upon grounding are graphed by a recording electrometer.

This bleed-off time, or decay rate, is practically instantaneous for foil or carbon impregnated films but shows on the graph as approximately 3 seconds due to instrument lag. Antistatic films such as RC AS-1200 show bleed-off times of the order of 2 seconds at ambient conditions while ordinary plastics show bleed-off times greater than 5 minutes. (It is interesting to note that there are only relatively slight differences between surface resistivity measurements on regular and antistatic polyethylene when *current* is used.)

The Environmental Health Group of Pan American World Airways at Patrick Air Force Base, Florida, is completing a study of the antistatic properties of various packaging films, under the direction of Dr. George Webster. This study involves a test technique of rubbing samples with wool, Teflon, or the material itself (giving three points on the triboelectric series), then grounding the sample and measuring bleed-off time as well as the level of charge generated.

CONCLUSION

Much static-related work has been and is being done by the Bureau of Mines, the National Fire Protection Association, the Army, the Navy and Air Force, the Aerospace Industries Association, NASA and other groups. Philosophies and interpretations differ over a wide area, too varied to be described in detail here. This one point is clear:

There is a dire need for updated, realistic and generally accepted standards covering the evaluation and proper application of antistatic films in specialized aerospace, military pharmaceutical and medical fields. For reasons both of safety and economy, let us hope that they are forthcoming in the very near future.

PARTIAL BIBLIOGRAPHY

Walkup, Lewis E., "Principles of Static Electricity," April 1951, available from *Battelle Memorial Institute*, Columbus, Ohio.

Silsbee, Frances B., "Static Electricity," Circular C 348, *National Bureau of Standards*, 1942.

Anderson, Dan C., "Brief Guide to Clean Room Packaging," Available from The Richmond Corporation, Box 1129, Redlands, California 92373.

Bolasny, Robert E. and Pearsall, Duane D., "Controlling Static in the Clean Room," *Contamination Control*, Sept. 1966.

Beach, Robin, "Controlling Static Electricity with Electrostatic Neutralizers," *Product Engineering*, Oct. 1953.

Anderson, Dan C., "Films Vs. Foil in the Packaging of Aerospace Hardware," available from the American Association for Contamination Control, 6 Beacon St., Boston, Mass.

Pilcher, Dr. J. Mason, "Pro and Con on Packaging Materials and Packaging Methods," *Contamination Control*, Sept. 1966.

Mondano, Ralph J., "Basic Concepts of Static Electricity," available from Custom Materials, Inc., 279 Billerica Rd., Chelmsford, Mass.

Beach, Robin, "Preventing Static-Electricity Fires," (three part article), *Chemical Engineering*, Dec. 1964, Jan. 1965, Feb. 1965.

Custis, Irving H., "Evaluate Electrostatic Properties of Thermoplastic Materials," *Package Engineering*, Dec. 1967.

Anderson, Dan C., "Antistatic Films Reduce Potential Packaging Hazard," *Paper, Film and Foil Converter*, March 1967.

Sereda, P. J. and Feldman, R. F., "Electrostatic Charging on Fabrics at Various Humidities," *Journal of the Textile Institute*, May 1964.

TRANSPORTATION REGULATIONS FOR AMMUNITION AND EXPLOSIVES

Moderator: Charles B. Smith
Office of Hazardous Materials
Department of Transportation
Washington, D.C.

TRANSPORTATION REGULATIONS FOR AMMUNITION AND EXPLOSIVES

SUMMARY

Fifty representatives of Government and industry attended this session. Mr. Alfred Fernandes, Naval Ordnance Systems Command; Mr. F. M. Ashcraft, Military Airlift Command; and Mr. K. E. Valant, Savanna Army Depot provided able assistance by serving as members of the panel.

Following the opening remarks which covered the organization and functions of the Office of Hazardous Materials, the Hazardous Materials Regulations Board, and the four operating administrations (Coast Guard, Federal Highway Administration, Federal Railroad Administration, Federal Aviation Administration) the moderator asked the attendees for any questions that might be covered under 49 CFR 170-190 and 46 CFR 146-149. The following subjects were discussed:

a. Handling vehicles loaded with hazardous materials during civil strife.

b. Placarding of vehicles during civil strife situations.

c. Compatibility of explosives loaded vans on railroads and ships.

d. Palletized and unitized cargo.

e. Compatibility of cargos other than explosives which might have equal or greater hazard than conventional explosives.

f. Container concepts suitable for all modes of transport.

g. Quantity/distance tables for storage vs transportation.

Mr. R. C. Herman, ASESB, gave an informative review of the United Nations Committee of Experts' work on classification and compatibility of explosives.

HAZARD CLASSIFICATION PER

DOD INSTRUCTIONS 4145.22 AND 4145.24 AND TB 700-2

(NAVORDINST 8020.3, TO 11A-1-47, DSAR 8220.1)

Moderator: William B. Thomas
Army Missile Command
Redstone Arsenal, Alabama

HAZARD CLASSIFICATION PER DOD INSTRUCTIONS 4145.22 AND 4145.24 AND TB 700-2 (NAVORDINST 8020.3, TO 11A-1-47, DSAR 8220.1)

SUMMARY

To begin the discussion, Mr. C. M. Masten, Aerojet General Corporation commented on the problems his company has in operating under the present document. This discussion is covered in a written paper, co-authored by Dr. J. H. Wiegand, also of Aerojet. Handouts of this paper were made to the attendees.

Following Mr. Masten's presentation, several comments were made from the audience agreeing with Mr. Masten that interim classifications were expeditiously available now from the Bureau of Explosives and expressing concern over a change to any system requiring submission for interim requests through the Services. Several other comments indicate that confusion exists as to the relation between DOD and DOT as to who is responsible for classifying DOD items for interstate transport. From a technical viewpoint, the largest single situation concerning the audience seemed to be the matter of interpretation of results on tests run according to TB 700-2 using the Bureau of Explosives impact test. The dilemma may be summarized as follows:

a. Interpretation of results is specified differently in TB 700-2 than in DOT regulation.

b. Composite propellants, which are Class B, Class 2, by all other criteria, frequently give positive results in the impact test which, if interpreted literally, would indicate the propellants to be Class A, Class 7.

c. Conversely, some double base, detonable propellants which are clearly Class 7, Class B by other tests, give negative impact test results.

d. The test is inherently unreproducible.

A survey of impact test results has been conducted by Dr. T. H. Pratt, of Rohm & Haas Redstone Research Laboratories and the results are given in this paper.

During further discussion of impact sensitivity, Dr. Billings Brown presented a graph of impact sensitivity vs specific impulse and commented on the trend towards increased sensitivity for new high energy propellants.

BLANK PAGE

IMPACT SENSITIVITIES OF SOME ADVANCED PROPELLANTS

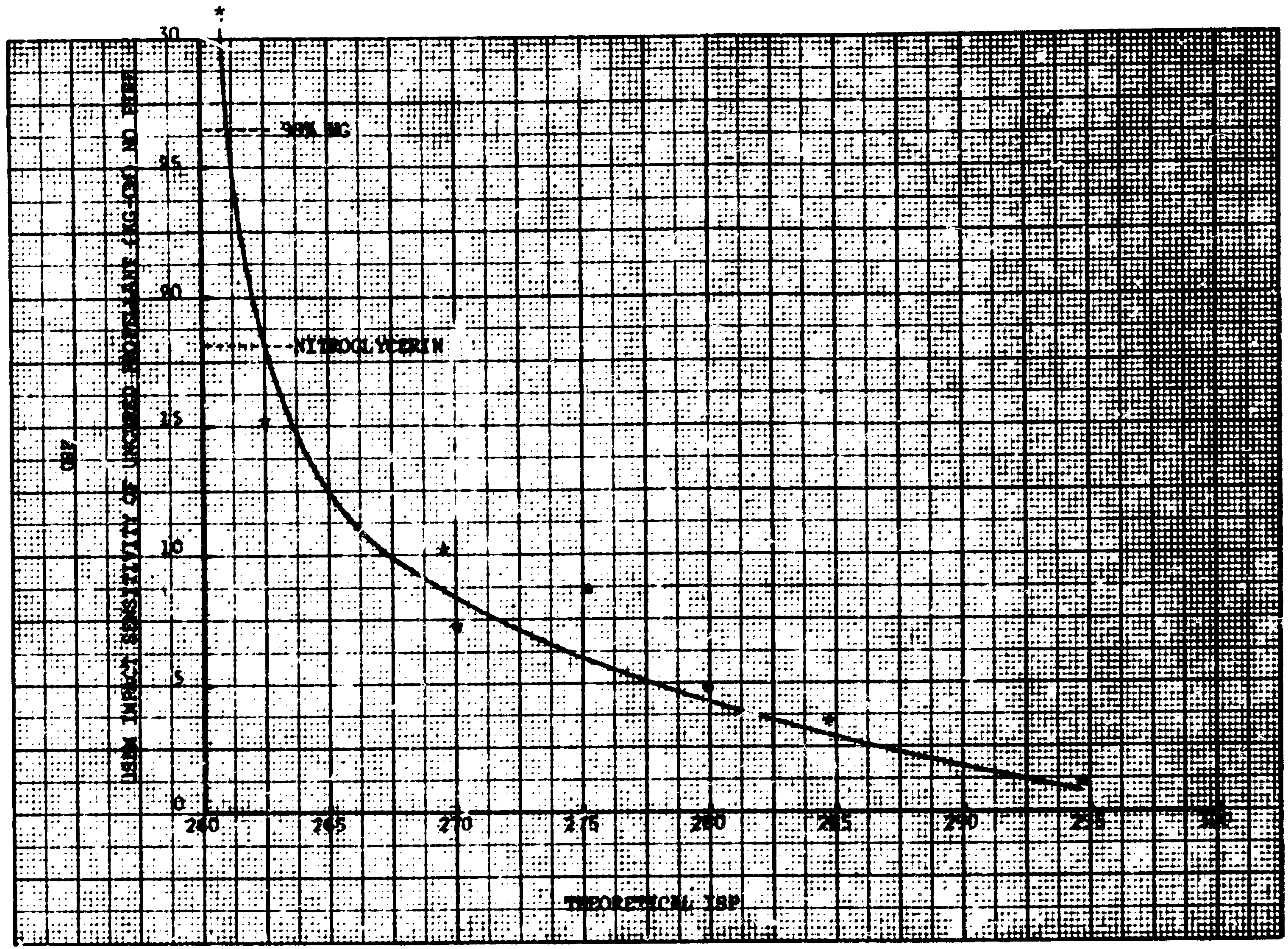
Remarks by Dr. Billings Brown
Institute for Defense Analyses

Previous speakers have presented impact test data for solid propellants used in current rocket motors. It is my purpose to acquaint you with similar results for some experimental propellants. In general, propellant sensitivity shows a consistent increase with delivered impulse. This increase in impact sensitivity (decrease in drop height) does not appear to be uniquely dependent upon any one of the three propellant constituents (fuel, oxidizer, binder), but seems to depend instead on the energy level of the resultant propellant. This synergistic effect from combining energetic ingredients has been reported previously.

The impact values of such propellants are far below (more sensitive than) the corresponding values for propellants in current use. Should these advanced propellants reach production status, remote handling for all phases of manufacture will be mandatory by today's rules. Additionally, I predict that new or modified tests will be required to determine more precisely the degree of handling hazard presented by each propellant. (See graph)

Other comments were made regarding the inapplicability of present TB 700-2 test requirements to pyrotechnic materials, particularly the powder types. Several comments from the group expressed concern for fast response to classification of SEA items which reportedly are required to be developed, loaded and delivered in as short as 90 days.

Capt. L. R. Olsen, USN Member of the ASESB invited proposals from those who have suggestions on research plans to better understand hazards or improve test methods.


USBM IMPACT SENSITIVITY OF UNCURED PROPELLANT (KG-CM) NO FIRE
98% NG
NITROGLYCERIN
THEORETICAL ISP
0
5
10
15
20
25
30
260
265
270
275
280
285
290
295
300

PROBLEMS REQUIRING CLARIFICATION FOR EFFECTIVE OPERATION OF TB 700-2

by

C. M. Masten & J. H. Wiegand
Aerojet-General Corporation
Sacramento, California

This report is prepared for the TB 800-2 session at the 1968 Annual Explosives Seminar in order that a written record of the oral presentation may be provided for further discussion.

As a member of the DOD-industry aerospace team, Aerojet-General Corp. has long recognized the outstanding direction and coordination of aerospace safety furnished by the ASESB. One of the bases of the excellence of the ASESB program has been the honest and full exchange of information and problems between the Board and the DOD contractors. In this spirit of mutual solution of problems, we would like to outline some of the difficulties and issues encountered in applying the 1967 revision of TB 700-2 to current and future contracts.

The following points are submitted for discussion and clarification.

a. The Department of Transportation authority and interface with DOD explosive classifications. At this point there seems to be no clear understanding of the DOD authority over military explosive shipments moving interstate. One view is that the DOD classifies security items, applying DOT criteria -- in essence, acting for the DOT within the framework of the DOT regulations. An opposing view is that the DOD may classify as it sees fit, making the parameters of Classes A, B, and C more -- or less -- restrictive than the DOT. Regardless of the viewpoint, TB 700-2 contradicts DOT classification requirements. A result is that some materials and items classified under TB 700-2 as Class A would be classified by the DOT regulations Class B when moving to NASA, or on company funded projects, or commercially. The inconsistency is illustrated by Table 1, which outlines the present DOT tests, and clearly shows they cannot be used in lieu of the test requirements of Section 3-13 of TB 700-2. In fact, the hazard classes are not directly relatable by this means.

b. The apparent decentralization of classification authority. Is the responsibility of assigning hazard classifications decentralized to "all DOD Agencies and Departments," as Section 2-2 and note B-4 in Appendix B of TB 700-2 seem to indicate? If it has been, then TB 700-2 is at variance with DOT Section 173.51(q). Experience with explosive

classification indicates problems with such a decentralization. If, in fact, the final authority for assigning classifications is only with the personnel designated by DOT, then it would seem that Section 2-2 should be revised.

c. The Bureau of Explosives Impact Test. (Section 3-11) As originally devised for use on explosive powders that could sift out of boxes during shipment, this test has validity in determining transportation hazards. Its use on large grains or cast materials is highly questionable. The initiation of a thin film of granular materials has little relation to the behavior of a large grain under the possible hazards of transportation. As to interpretation, with the variability typical of this test the determination of the initiation point cannot be done with statistical significance with only 10 total specimens. Therefore, there is wide variation in results between laboratories, and between series in the same laboratory. Most important of all, results from the impact tests do not correlate with other tests. When a material has been shown to be detonable with the Number 8 cap test, the impact test has value in determining ease of initiation. Therefore, consideration should be given to requiring this test when a Number 8 blasting cap produces a detonation, as stated in the 1962 edition of TB 700-2. Although the impact test has no value in determining the differences between Class A and B, it has some value in establishing the upper limits of Class A.

d. The mandatory inclusion and interpretation of the Bureau of Explosives impact test in Section 3-13. By this test, TB 700-2 upgrades to Class A many propellants classified as Class B under DOT regulations. First, at the 10-inch drop height on the Bureau of Explosives Impact Apparatus, DOT Section 173.53 allows up to 50% positives (explosions) for Class A Explosives Types 2 and 3, and does not require this test for Types 1 and 4 through 9, as shown in Table 1. TB 700-2 3-13a(3)(b), however, makes the 10-inch drop test mandatory, with "an explosion" resulting in a Class A classification. Considering next the 3-3/4 inch drop height, DOT places Types 4, 5, and 6 explosives in the Forbidden class for any positive, allows up to 50% positive for Types 2 and 3, and does not require this test for Types 1, 8, and 9. TB 700-2 Section 3-13a(2)(a) seems to indicate that any explosion at this height results in a classification of "Restricted," which is higher than Class A.

In order to provide a basis of discussion at this point, Tables 2 and 3 were prepared. Table 2 shows some of the tests on AGC propellants in high production motors still in use; Table 3 shows R&D propellants under development or in current R&D motors. Under the strict interpretation of the Bureau of Explosives impact test results in Section 3-13, all of these propellants would be designated Class A, yet extensive experience indicates the true hazard level is Class B.

e. <u>The classification of materials that explode but do not detonate during unconfined burning</u>. There is no classification in TB 700-2 for materials exhibiting this behavior. Section 3-13a(2)(b) places materials that detonate during unconfined burning in the Restricted category. Sections 3-13a(3)(c) and (4)(a) designate as Class A materials that do not "explode" during unconfined burning. Where should materials that deflagrate rapidly even to the extent of low order explosion, but do not detonate, be placed? Such materials exist and are being produced for the DOD.

f. <u>The responsibility for obtaining interim classifications for initial shipments of R&D items</u>. There is no provision for manufacturers to obtain interim classifications on contracts that call out the 1967 revision of TB 700-2, whereas under the 1962 version, such interim classification could be obtained expeditiously through the Bureau of Explosives. Before a motor or other device can be classified under the 1967 revision of TB 700-2, the tests in Chapters 4 or 5 are mandatory. The alternatives are accepting a presumed Class A classification under Section 5-3(c), which prevents air shipments of small samples and substantially increases transportation costs, or presumably proving by extrapolation under Section 2-2(a) that the new item is analogous to an existing item under some procedure not yet defined. When tests are required, such tests are usually run at a DOD facility, necessitating shipment of a limited number of items from the manufacturer's plant; the method of classification of such limited shipments is not delineated formally. Many companies obtain these interim shipping classifications directly from the Bureau of Explosives in conformance with the DOT regulations. This situation was covered in the 1962 edition of TB 700-2; it is not covered in the 1967 revision.

g. <u>Omission of the Bureau of Explosives</u>. Omission ignores the present and significant role of the Bureau of Explosives in facilitating the shipment of propellant, motors, and explosive items with an impressive record of safety. The Bureau, because of its experience and knowledgeable personnel, gives a large number of interim classifications expeditiously (an average of 9 days for 86 approvals for Aerojet, including a number of crash efforts taking less than one day). In addition, the Bureau, as the agent for Canadian and United States railroads, has a "need-to-know."

DOT TESTS
(SECTIONS 173.51 and 173.53)

	Stable, 48 hrs at 75°C	Deflagrates, squib or s. fuse	Detonates from squib or s. fuse	#8 bc pos.	#8 bc neg.	3 3/4 in. drop one pos.	3 3/4 in. drop 100% neg.	3 3/4 in. drop, 50% or more pos.	3 3/4 in. drop 50% or more neg.	10 in. drop 50% or more pos.	Squib detonates item in shipping container	So designated by Bureau of Explosives
Type 1 (black powder, etc.)	X	X			X							
Type 2 - Solid Expl. with liquid Expl. Ingredient	X			X					X	X		
Type 3 - Solid Expl. with no Liquid Expl. Ingr.	X			X					X	X		
Type 4 (initiating expl.)	X		X					X				
Type 5 Desensitized Liquid Expl.	X			X			X					
Type 6 - Liquid Expl.	X					X						
Type 7 - Blasting caps	X											
Type 8 - MSC, Not types 1 - 7	X											X
Type 9 - Propellant Explosive, Solid	X										X	

Table 1

HAZARD TESTS AND CLASSIFICATION ON ROCKET COMPOSITE PROPELLANTS

	Bu Explosives 3 3/4"	Impact (1) 10"	BuMines 50% Pt/2 Kg	#8 EC, 2" cube	Attenuation NOL Card Gap	Unconfined Burning 2" cubes	DOT Class
A	3+, 7-	10+	22 cm	Burned	---	35 Sec.	B
B	6+, 4-	10+	19 cm	Burned, 18-22 sec	Neg. 0"	24 - 26 Sec.	B
C	7+, 1s, 2-	10+	16 cm	Burned, 21-30 sec	Neg. 0"	26 - 27 Sec.	B
D	1+, 9-	2+, 8-	23 cm	Burned	---	Burned	B
E	5+, 5-	10+	21 cm	Burned	Neg. 0"	32 Sec.	B
F	7+, 3-	10+	10 cm	Burned	---	Burned	B
G	2+, 8-	3+, 7-	24 cm	Burned	---	Burned	B
H	6+, 1s, 3-	10+	20 cm	Burned	Neg. 0"	24-26 Sec.	B
I	2+, 8-	10+	84 cm	Burned	Neg. 0"	63 Sec	B
J	4+, 6s	9+, 1s	35 cm	Burned, 30-34 sec	Neg. 0"	32 - 38 Sec.	B
K	3+, 7-	10+	15 cm	Burned	---	30 Sec.	B
L	3+, 7-	10+	---	Burned	---	Burned	B

(1) + = Explosion, flame, or noise 3= Decomposition, smoke, no noise - = No reaction

Table 2

CURRENT PROPELLANT HAZARD TESTS AND CLASSIFICATIONS

	Impact Tests (2)			Detonation Test		DOT Class
	Bu. Explosives		Bu. Mines	NOL Card Gap		
	3-3/4" Drop	1[illegible]" Drop	5% Pt [illegible]m/2Kg	Result	Attenuation	
T	8+ 2s	10+	24	Neg.	0-in.	B
U	10-	1s, 9-	38	Neg.	0-in.	B
V	3+, 4s, 3-	10+	20	Neg.	0-in.	B
W	8+, 2-	10+	23	Neg.	0-in.	B
X	8+, 2s	10+	15	Neg.	0-in.	B
Y	6s, 4-	9+, 1s	26	Neg.	0-in.	B
Z	6+, 4s	10+	35	Neg.	0-in.	B

Note 1: All of the propellants burned under the #8 BC test; none detonated during unconfined burning.

Note 2: + = Explosion, flame, or noise
s = Decomposition, smoke, no noise
- = No reaction

Table 3

COMPARATIVE SENSITIVITY DATA ON SOLID PROPELLANTS

by

T. H. Pratt
Rohm and Haas Company
Redstone Research Laboratories
Huntsville, Alabama

The impact test as specified in Department of the Army Technical Bulletin TB 700-2, "Explosives Hazard Classification Procedure," 19 May 1967, for military classification of solid propellants is inconsistent with present military classifications of missile systems. The impact sensitivity of classical Military Class 2 propellants (composites) is of the same order as the impact sensitivity of classical Military Class 7 propellants (double-base and nitramine-oxidized propellants). Therefore, impact data cannot be used to differentiate between Military Class 2 and Military Class 7 propellants as they are accepted by the industry. Indeed, impact data can, on occasion, indicate less hazard for Class 7 propellants than for Class 2 propellants.

Redstone Research Laboratories of Rohm and Haas Company requested impact data from propellant manufacturers to demonstrate this point. Data were contributed by Aerojet General Corporation, Scramento; Atlantic Research Corporation; Hercules Incorporated, ABL; Lockheed Propulsion Company; Rocketdyne, McGregor; Thiokol Chemical Corporation, Elkton Division; Thiokol Chemical Corporation, Huntsville Division; and United Technology Center. Selected data from these manufacturers have been tabulated.

Aerojet General Corporation, Sacramento Plant						
Designation	Impact[a]	Impact[b]	Impact[c]	Card Gap[d]	Classification ICC	Classification Military
ANB-3220	38	10-	1s, 9-	0	B	2
AXD-3291	38			1.85-1.9	B	7
AAB-3205	35	6+, 4s	10+	0	B	2
AAP-3323-1	28			1.0-1.5	B	7
ANB-3206	26	6s, 4-	9+, 1s	0	B	2
ANB-3213	23	8+, 2-	10+	0	B	2
ANB-3214	20	3+, 4s	10+	0	B	2
ANP-3207	15	8+, 2s	10+	0	B	2
AAP-3249	14			0	B	2

[a] Bureau of Mines Impact Apparatus, 50% point, cm/2 kg.
[b] Bureau of Explosives Impact Apparatus, 3-¾ inch drop
t = explosion, flame or noise; s = decomposition, smoke, no noise; - = no reaction; ten trials.
[c] Same as b except 10-inch drop.
[d] Standard card-gap value, inches, per TB-700-2

Atlantic Research Corporation			
Designation	Impact	ICC Classification	Type
Arcite 373D	>300	B	ARCAS
Arcadene 152	>300	B	Sled
Arcocel 333D	230	B	DB, AP, Be
Arcocel 319BR	175	A	DB, RDX, AP
Arcocel 365	125	B	DB, AP

Bureau of Mines Impact Apparatus, kg-cm. All formulations >3.75 on Bureau of Explosives Impact Apparatus.

Lockheed Propulsion Company				
			Classification[c]	
Designation	Impact[a]	Card Gap[b]	ICC	Military
LPC-1010	>25	1.25	A	(7)
LPC-702A	18	0	B	2
LPC-547	15	0	B	(2)
LPC-1008A	12	1.52	A	(7)
LPC-1005A	12	1.05	B	
LPC-1014	12	0.67	(B)	(2)
LPC-1003C	10	0.63	B	(2)

[a]Bureau of Explosives Impact Apparatus, 50%, 2 kg weight, 0.075 × 0.20 inch diameter sample.
[b]Standard card-gap value, inches, per TB 700-2.
[c]Expected classifications shown in parentheses.

Thiokol Chemical Corporation, Huntsville Division					
			Classification		
Designation	Impact[a]	Card Gap	ICC	Military	Type
DTS-6501	>100			(7)[c]	Experimental[b]
TP-H-7040	52.0	0	B	2	SPRINT
TP-H-8126	45.0	0	B	2	Nike Zeus
TP-H-1011	40.0	0	B	2	Minuteman
TP-H-7036	40.0	0	B	2	Castor II
TP-H-7034	32.0	0	B	2	Spartan

[a]Modified Olin-Mathieson Impact Tester, kg-cm, 2 kg weight, 10 consecutive negative tests.
[b]Experimental smokeless propellant using a nitramine oxidizer in an energetic binder.
[c]Expected classification shown in parentheses.

AMMUNITION LOADING AND ASSEMBLY-EQUIPMENT

LAYOUT, DESIGN AND AUTOMATION

Moderator: C. R. Goff
Director, Safety & Plant Protection
Day & Zimmermann, Inc.
Lone Star Division
Texarkana, Texas

AMMUNITION LOADING AND ASSEMBLY-EQUIPMENT LAYOUT, DESIGN & AUTOMATION

SUMMARY

A discussion of some of the automatic equipment for loading various types of ammunition components was held after the slides were shown. Several attendees to the session brought out that the future of automation in the ammunition industry would require that in the initial design stage of new items, that the requirements of mechanized assembly would have to be given a greater share of consideration. For example, metal parts tolerances would have to be established that would permit mechanical assembly and utilizng automatic feeding equipment. A representative from Picatinny stated that Production Engineering is now working very close with design groups at Picatinny to assist in studying new types of ammunition that could take advantage of mass production techniques that have been developed in recent years.

It was also brought out that several plants had been asked to create new concepts in loading areas and it was requested that these plants, when working out their new concepts, include to the greatest extent possible, automation, especially in the loading of the explosive items. It was unanimously agreed that automation is the only real answer to true safety in the ammunition industry and that the hazardous stages of ammunition loading be automated at the earliest practicable date.

Col. B. B. Abrams, USA, Chairman of the Armed Services Explosives Safety Board, addressed the group on the subject of up-dating facilities at the ammunition plants. He indicated that although money was required for large-scale modernization programs, quite a bit could be accomplished within currently available resources by improving procedures and encouraging the application of ingenuity among the work force. At the same time, effort should be made to obtain smaller sums of money for improvements in the near future, fully supported with strong justification; and finally, long range plans for extensive mechanization and automation requiring large expenditures of funds should be developed and submitted.

The excellent comments made by the attendees proved that their efforts are directed towards a sizeable reduction in injuries and accidents and that the overall efficiency of the ammunition loading industry is of primary importance.

BLANK PAGE

EXAMPLES OF AUTOMATION DESIGN AT THE LONE STAR ARMY AMMUNITION PLANT

by

Thomas P. Hill
Day & Zimmermann, Inc.

Members of the Armed Services Explosives Safety Board, guests; this special session today is for the purpose of discussing Design and Automation in Ammunition Loading and Assembly. Complete automation of loading explosives into various ammunition components has been and will continue to be the ultimate goal o' Day & Zimmermann, Inc.

I have some slides of some of our more critical explosive loading operations that we have automated as far as the actual loading procedures are concerned.

Since detonator loading is one of our more important functions, we average loading 28 different types for a total of 23 million per month. Here are some of the ways we have eliminated injuries and improved quality and costs by automation:

Slide #1
Old Type Jones Loader with Hand Operations.
Rate of Production 10,000/Shift.

Notice the difference between our present Jones Loader in the next slide and the original equipment. All employees have been eliminated. Explosives are being automatically dispersed, and detonators are being packaged.

Slide #2
Jones Loader Showing
Automatic Detonator Packaging.

This slide shows the equipment installed on a Jones Loader. This machine is now completely automated except for recharging of explosives and that also is remotely done. This equipment is now undergoing trial operations and we expect to conclude such tests sometime in November. During these trial operations we are discouraging visits for observation. We have much work to do and can do it better with visitors absent.

Slide #3
Frictionless Loader for Azides,
RDX, and Delays.

Type Powder	Charge Weight	Accuracy	Cycles Per Minute
RDX	25 Mg.	± 2 Mg.	38-42
Delay Composition	90 Mg.	± 2.5 Mg.	38-42
Delay Composition	40 Mg.	± 2.5 Mg.	38-42
Delay Composition	15 Mg.	± 2 Mg.	38-42
RD 1333 Lead Azide	50 Mg.	± 2 Mg.	38-42
RD 1333 Lead Azide	70 Mg.	± 2.5 Mg.	38-42

Slide #4
Chamlee Loader for Azides and RDX

RDX	25 Mg.	± 1 Mg.	38-42
RD 1333 Lead Azide	100 Mg.	± 2 Mg.	38-42
Dextrinated Lead Azide	100 Mg.	± 3 Mg.	38-42

Slide #5
Cargile Loader for Primer Mixes and Azide.

Dextrinated Lead Azide	100 Mg.	± 3 Mg.	38-42
NOL No. 130 Primer Mix	18 Mg.	± 2 Mg.	38-42

Each of these loaders not only eliminated the hazardous hand scooping of sensitive initiating explosives but made it possible to design a completely automated detonator loading machine known as a Transomater.

Slide #6
Transomater. Rate of Production 20,000/Shift.

Slide #7
Automatic Burster Loader - (M19 or M47)
16 Units/Min.

This Machine automatically positions the empty burster tube, feeds 3 RDX pellets, and consolidates. This is repeated 7 times for a total of 21 pellets, automatically faces the burster to the proper height and ejects the burster on a belt that moves the burster outside the bay for inspection and packaging.

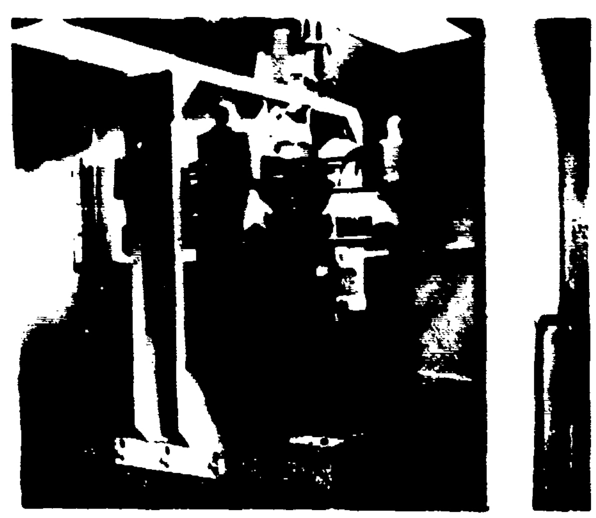
An operation that has been a critical safety problem is the primer torquing of the 81MM Mortar.

Slide #8
Automatic 81MM Mortar, Primer Torque Machine

This machine automatically screws in and torques the primer at a rate of 20-22/minute.

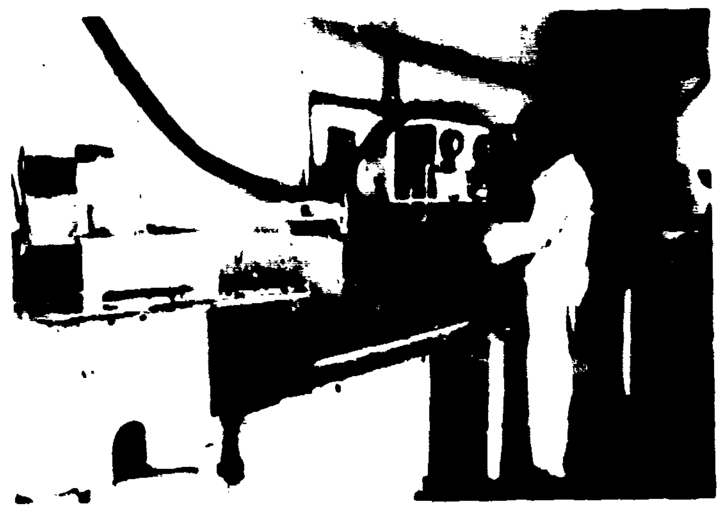
Slide #9
Torquing Bay.

The cups that the mortars are setting in vertically are parts of a chain conveyor that feeds through the torquing machine previously shown.



Slide #10
Automatic Facing Machine.

This machine automatically faces the LAW Warhead. It can be retooled to face similar sized components.



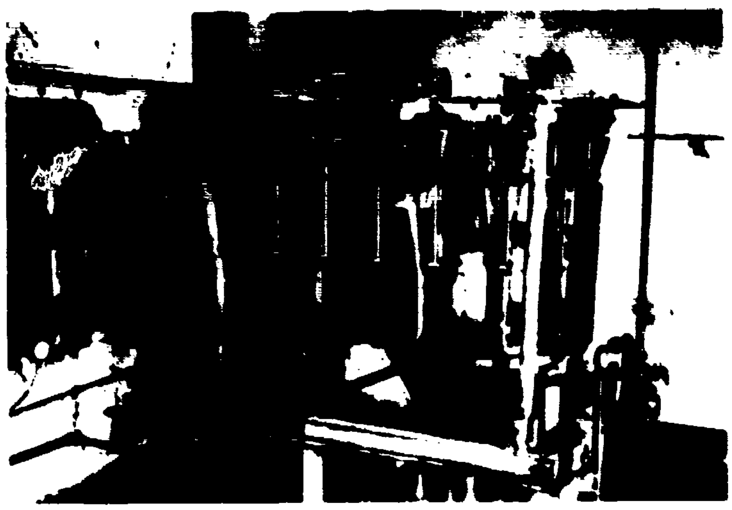
Slide #11
Loading Bay.

The operator feeds the conveyor chain with Warheads; and they are automatically transported through the wall, into the machine, faced, and transported back into the loading bay.

Slide #12
M26 Grenade Fuze Torquing Machine.

One item we handle with great care is the M26 Hand Grenade because of the extreme sensitivity of the fuze and ease with which it can be fired. The fuze torquing operation is remote and automatic. Fuzed grenades are transported through the steel barricade by chain conveyor, through the fuze torquing machine, and into the next bay. Machine rate - 40-42 units/minute.

In addition to this steel barricade containing the fuze torquing equipment, the machine is so located in the barricade that should a fuze be accidentally armed during torquing, there is sufficient time lapse prior to the grenade leaving the barricade to insure that any explosion will be contained within the barricade. Further, tests have been made to insure that there would not be propogation from one holding fixture to the next.



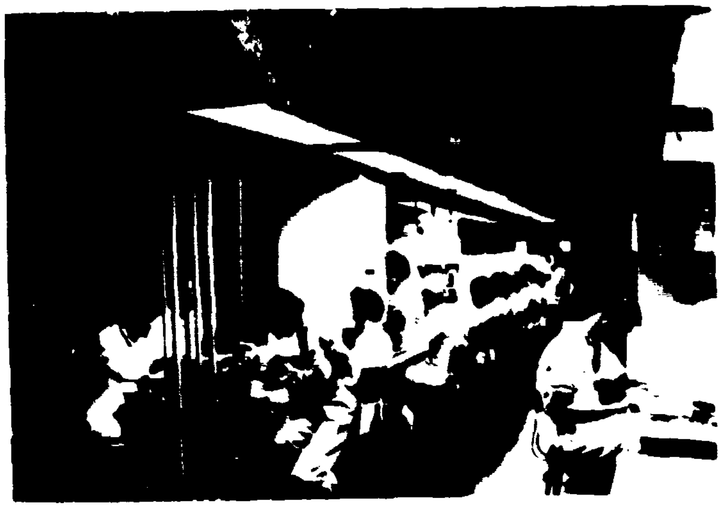
Slide #13
Automatic Primer Loader - Black Powder.
Rate - 73-75 Units/Minute

Loading of primers with Black Powder not only is hazardous when done by employees but creates a housekeeping problem. This machine is fed by a chain conveyor through dividing wall, automatically loading the primer with Black Powder, and back through the wall to the stations where the primer bodies are inserted into the machine and loaded primer bodies removed.

Slide #14
Primer Body Insertion and Removal Station

This slide shows the primers being inserted and removed.

To more graphically describe the numerous advantages of automation, especially from a safety standpoint, here are four photos of a hand line utilized in assembling the M557 Fuze:



Slide #15
F-15 Hand Line, M557 Fuze.

Slide #18
F-15 Hand Line, M557 Fuze

This Line employs 128 assembly operators to produce approximately 8,500 M557 Fuzes per shift.

In contrast, we have a completely automated production Line for assembling the M557 Fuze.

Slide #19
M5 Automatic Line, M557 Fuze

Slide #16
F-15 Hand Line, M557 Fuze.

Slide #17
F-15 Hand Line, M557 Fuze.

This Line is capable of running 15,000 fuzes per shift with only 60 assembly operators. This not only will result in a considerable reduction in cost, better control over quality because of reducing the human element, but has reduced the human exposure over 50% in numbers of employees exposed alone. This is additional safety that would be difficult to measure in an automated line such as this is, as a result of the actual handling of explosive loaded components by machinery rather than employees.

EXPLOSIVES FACILITY PLANNING & DESIGN

Moderator: C. J. Stevens
Naval Facilities Engineering Command
Washington, D. C.

EXPLOSIVES FACILITY PLANNING & DESIGN

SUMMARY

After brief introductory remarks by the moderator, Mr. Charles R. Watkins, Hq, USAF, presented a paper entitled "The Influence of Explosive Safety Requirements on the Development of Air Force Base Master Plans." This paper discussed the influence of safety clearance criteria on the design of Air Force Base Master Plans. Examples of several types were described, such as the location of storage facilities where ample space was available; the enlargement of an existing area due to a change in mission, which required the acquisition of additional land partly by purchase and partly by obtaining restrictive easements; and a situation where enlargement of the existing area would require additional land both by purchase and easement. However, a reorientation of the storage area resulted in a reduction in the area to be purchased and a larger easement, with a net reduction in over-all land costs.

This paper, illustrated with slides, was followed by a talk by Mr. Donald B. Pledger, a team captain in the Special Facilities Planning Section, Master Planning Branch, Office of Assistant Commander for Facilities Planning, Naval Facilities Engineering Command. His talk, entitled "Master Planning for Ordnance Facilities," described the need for, and the procedures involved in, the preparation of Master Plans for Naval Shore Activities, with particular emphasis on ordnance activities. His talk was further illustrated with slides showing portions of the Naval Ammunition Depot, Bangor, Washington. His team is currently preparing a Master Plan. (Both papers were well received and generated considerable discussion.)

The moderator gave a brief description of the current acquisition of land, including the town of Port Chicago, California, to provide adequate safety distances from the ammunition piers.

From the design point of view, considerable discussion was generated over such special items involved in ordnance design as primary lightning protection, conductive floor finishes, explosion-proof lighting, explosion-proof cranes, blow-out type of construction, dehumidification of production and storage areas, and the use of other materials beside grass to protect the earth cover on magazines. Time did not permit discussion on this.

THE INFLUENCE OF EXPLOSIVE SAFETY REQUIREMENTS ON THE DEVELOPMENT OF AIR FORCE BASE MASTER PLANS

by

Charles R. Watkins
Directorate of Civil Engineering, Hq, USAF
Bolling Air Force Base, Washington, D.C.

The application of safety clearance criteria exerts considerable influence in the design of most Air Force Base Master Plans. Briefly, master plans are the official Air Force documents that guide the orderly and systematic development of Air Force Bases. They portray its geographical and physical characteristics in graphic form. The locations of existing facilities, space for expansion and the provision of sites for future requirements are important elements of these plans. From this brief description, one can see that locations for explosive facilities and their attendant clearance requirements are important considerations in this planning. This is especially true for the storage of munitions where large quantities of high explosives are concentrated in one area and significant safety clearances are required. The safety clearance mandate for parked armed aircraft is also an important consideration, although the surrounding protective area is not normally as large.

Figure 1 illustrates the inhabited building limitations for three separate hazardous areas on a typical Air Force Base as denoted by the red, blue, and yellow colors. Within these areas, no personnel, equipment, or structures are permitted other than those directly concerned with the operational functions. Areas 1 and 2 portray the inhabited building clearances required around explosives loaded aircraft, while area 3 shows the same for the bulk ammunition storage area. By comparing the size of these areas with the rest of the base, it is apparent that they occupy a considerable portion of the available real estate.

The acquisition of real estate is a problem that confronts the Air Force at many large installations. Real estate is expensive, often hard to find and difficult to acquire. Neighboring communities grow toward these bases hindering their expansion capabilities. Increased business opportunities and the need for additional housing are the primary limiting factors. This condition is often further aggravated by the lack of adequate zoning controls. If conditions were ideal, the Air Force could envision future expansion requirements and plan accordingly. Experience has shown, however, that this is seldom the situation. Changing weapons systems, operational concepts, and missions in conjunction with the difficulty of justifying land acquisitions for

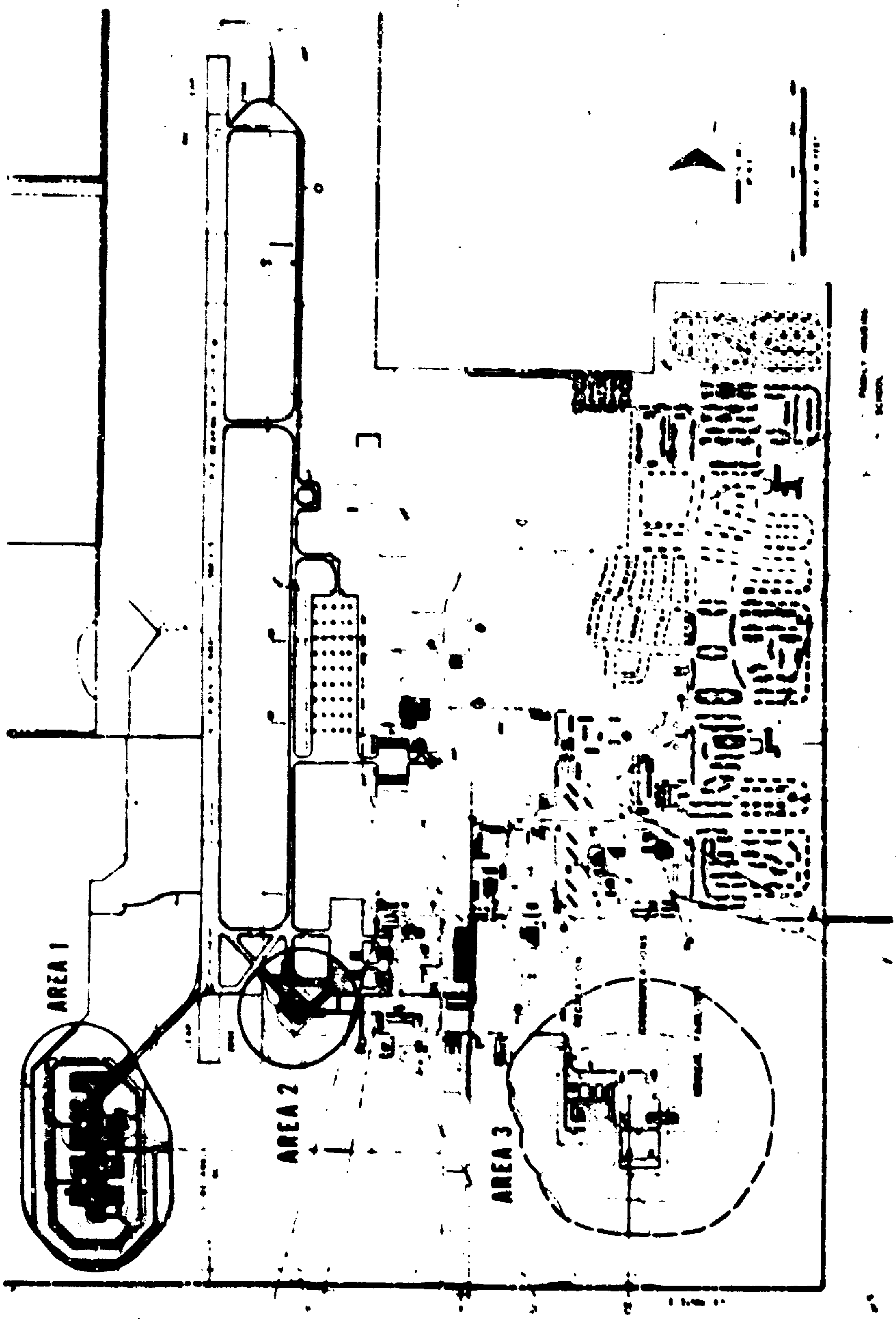


Figure 1

unforeseen requirements are major impediments. It, therefore, behooves the Air Base Planner to make the best use of his design ability to adapt to the circumstances at hand.

With the exception of Southeast Asia and possibly a few other scattered locations, the Air Force is not presently developing any virgin sites. Our major concern is the master planning of existing hard core installations and the expansion of existing storage facilities. This situation is even prevalent at some of the SEA locations.

Wherever possible, munitions storage sites are located near the base periphery with sufficient adjacent open area to permit later expansion toward the main base. At locations where storage facilities can be sited in this manner, the future expense and time onsuming legal entanglements can be avoided. Figure 2 illustra a good example of proper initial base planning. Ample space is available at the base shown for later expansion to the North and South without complications. The single hatched lines indicate the inhabited building clearances from the existing explosives storage structures, which are the fourteen buildings in the approximate center of this area. The cross hatched area indicates the additional space required to double the storage capacity by adding seven structures each, to the North and South of the existing facilities. All clearances are satisfied well within the existing confines of the base. Additional space is also available for further expansion to the South.

Although Figure 2 indicates a relatively simple example of good planning, it shows what can be done when conditions are ideal. The base used in this illustration was developed in the middle fifties and a comprehensive master plan was prepared prior to the acquisition of land for its implementation. It was initially designed to accommodate a specific mission with multimission flexibility. Provisions were included for possible mission changes, and envisioned future expansion. As stated, this base was planned and constructed under ideal conditions, a situation not generally available for the majority of those bases in the Air Force inventory.

Figure 3 shows the layout of an installation where the Air Force was unable to develop an explosives storage area under the favorable conditions shown on Figure 2. This base was built during WW II to support flying training activities with a minimal need for munitions storage. It was deactivated at the close of the war and reopened in the early fifties for a tactical type mission with an attendant requisite for the storage of sizeable quantities of munitions. Since sufficient space was not available within the base boundary, the acquisition of additional real estate was necessary to afford proper protective clearances. The single hatch lines delineate the area purchased in fee, while the cross-hatched lines indicate the area covered by restrictive easements. Where practicable, restrictive easements are used by the Air Force in

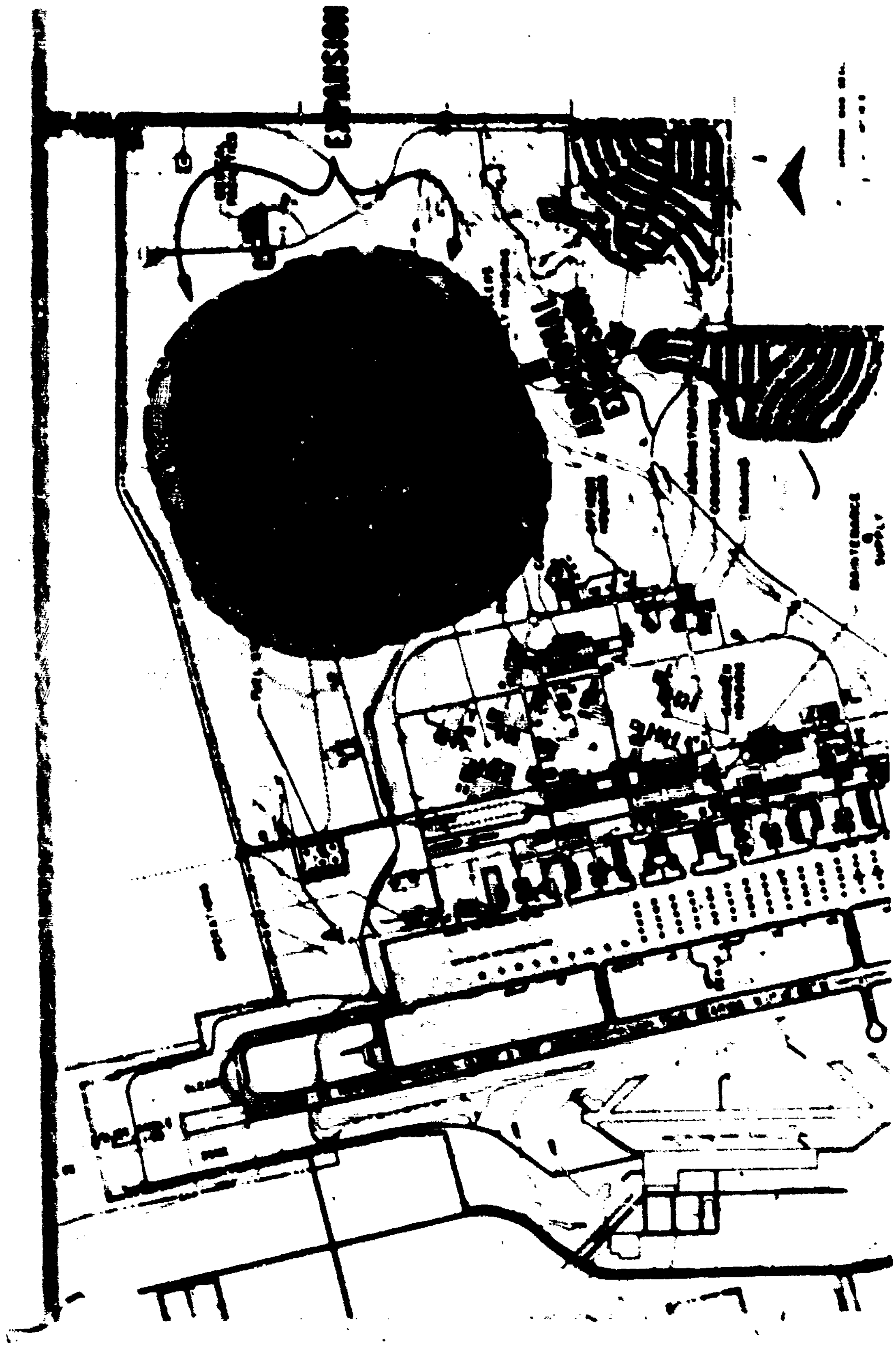


Figure 2

obtaining protective covenants over adjacent properties. It is less expensive than fee simple and is usually more palatable to the owners. This method, however, is only possible where the bordering property is agricultural or of comparable utilization, since habitable structures are not permitted. At the time of initial real estate action, agriculture was the established land category for this installation. If residential, commercial or other high type utilization had been predominant, possession may well have been denied by acquisition difficulties. An extremely high price tag would have been the primary deterrent. In addition, the time-consuming litigation required for the almost certain condemnation proceedings would have been a further constraint.

Figures 2 and 3 show two varied situations concerning the storage of explosives and their related clearance requirements. Although the latter did not offer the capabilities available at the former, its deficiencies cannot be attributed to poor planning in the true sense. The base was well designed to serve the original mission, and present-day expansion requirements could not be envisioned at the time. The problems encountered at this base and comparable bases, suffering from the same "growing pains," alerted the Air Force to the need for astute planning in the augmentation of these installations. There is a continuing demand for good planning.

One may logically ask, how can good planning help in the siting of hazardous facilities, specifically in situations where the base real estate is in short supply? Frequently, the only answer is the acquisition of additional land, but even these situations can be enhanced by the application of good design techniques. Figure 4 outlines a portion of an Air Force Base housing the explosives storage area. Existing storage structures are shown in solid color, and the two encircling series of long broken lines set forth their protective clearances. Public highway and inhabited building safety clearances are denoted by the inner and outer lines respectively. The purchase, part in fee and part in easement of the large area north of the fence line was necessary to protect these clearances. The fee area is bounded by short dashed lines. Easements are similarly shown with the addition of the letter E. Superimposed on the existing plan is a revised layout which presents a greatly improved configuration from the real estate standpoint. The revised roads are shown with heavy black lines and the structures in the open outline. The solid lines encompassing these facilities indicate revised clearance requirements. Corresponding reduced fee and easement areas are shown in solid and short broken lines respectively, while the single hatched lines designate the real estate that could have been eliminated by reorienting these facilities. Although there are obvious deficiencies in the existing layout, the example used is an exception to normal Air Force planning accomplishments. The actual base involved is in a remote location and the adjacent area is mostly wasteland. However, the main point of the illustration is to show that sound planning judgment

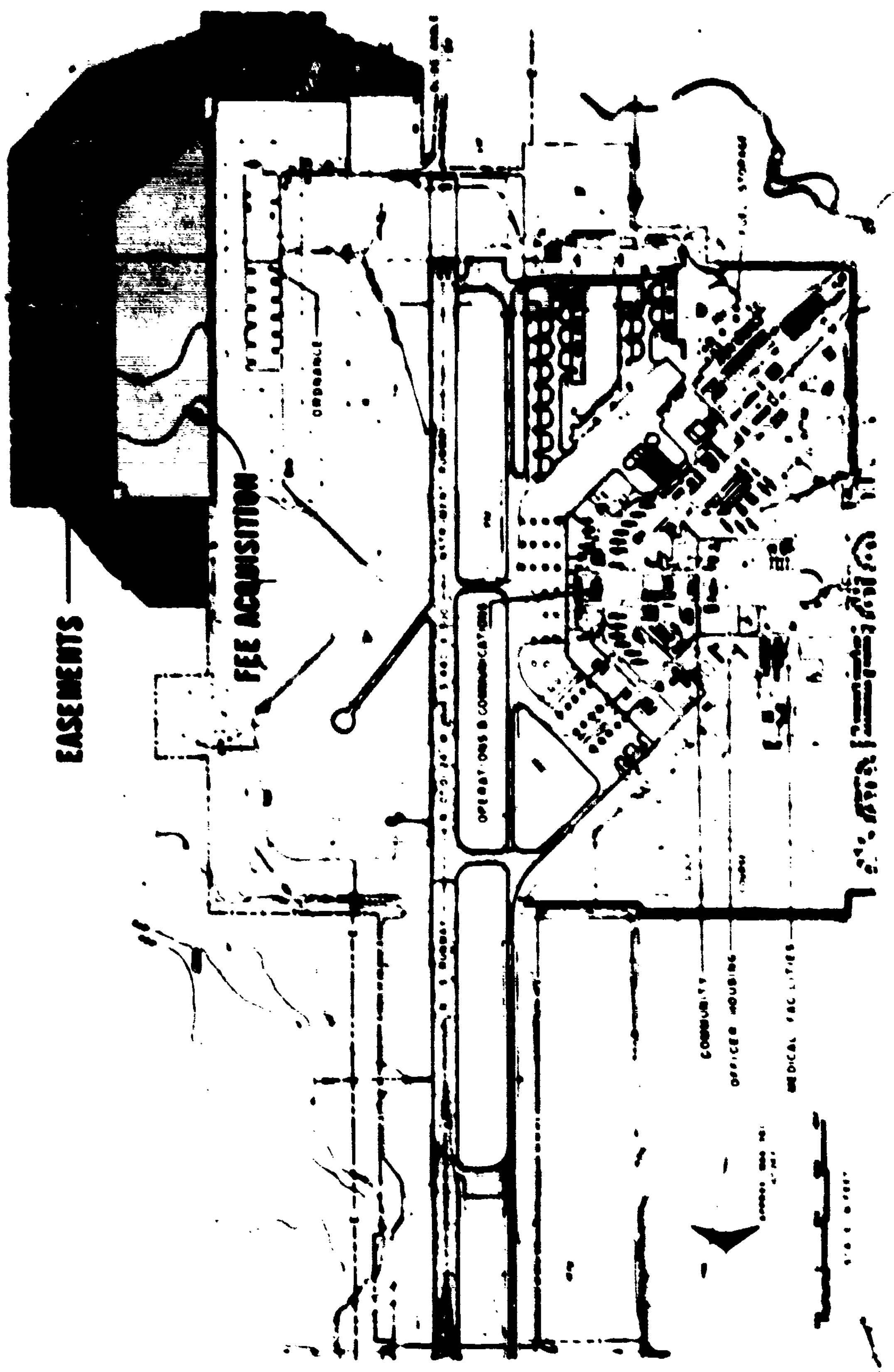

EASEMENTS
FEE ACQUISITION
ORDNANCE
OPERATIONS & COMMUNICATIONS
COMMUNITY
OFFICER HOUSING
MEDICAL FACILITIES

Figure 3

Figure 4

can generally improve any given situation. In this case, a simple relocation of facilities was the only requirement.

The siting of other hazardous facilities also influence air base design, but their locations are more firmly established by operational requirements. The proximity of parked armed aircraft to the runway system is an example. In this and similar circumstances, the major planning effort should be directed toward the siting of adjacent items. The problems of future site adjustments can be avoided if clearance criteria can be satisfied in the initial planning phase.

Barricades or revetments are often used as a planning tool in the reduction of safety distances from hazardous items. The opportunity for increased operational capabilities or the conservation of premium space may warrant the additional cost of their construction. In this connection, development and utilization of a steel arch, earth covered magazine (which permits reduced clearance requirements) has been extremely helpful in solving some difficult planning problems. There is a continuing need for this type development and further research for new methods of storing and handling munitions.

Although the preceding is little more than a "thumb-nail" sketch, it portrays the influence of explosive safety requirements on the development of Air Force Base Master Plans. In addition, it outlines the need for constant surveillance and ingenuity. Through the use of various design techniques, it is possible to comply with quantity-distance standards and develop operationally efficient storage sites.

SYSTEMS SAFETY & PLANNING

Moderator: Robert F. Sellars
Martin Marietta Corporation
Orlando, Florida

BLANK PAGE

SYSTEM SAFETY ENGINEERING WITHIN THE U. S. ARMY MATERIEL COMMAND

by

Harold E. Wells
Army Materiel Command
Washington, D. C.

AMC's MISSION

The basic mission of the AMC is the development and procurement of Army materiel, based on Department of the Army approved user requirements. Subsidiary missions include basic research, technical intelligence, storage and distribution, transportation, demilitarization, and disposal of this materiel.

SAFETY IN PERSPECTIVE

The Army established a formal system safety engineering policy in Feb 67, which was an outgrowth of the recognized need for orderly integration of safety requirements into development programs. In essence, this policy prescribes that total system safety be achieved by:

1. Preengineering safety analyses of design concepts and post engineering evaluations.

2. Application of effective managerial controls during development, test, and production.

3. Efficient administration of logistical and operational procedures.

Although safety within the broadest definition encompasses the entire life cycle of a system, true safety engineering is generally confined to the development and test phases, the most appropriate periods in which to integrate safety engineering principles. It is at these points in a program that design can best attack the hazards which we desire to eliminate.

During initial contract negotiation, definition of the safety effort is most important. A contractor must be paid for his efforts and unless it is properly defined and adequately managed, later "catch-up" efforts will cost more and produce less. There is no point in paying for more than one needs, however, sufficient safety engineering must be included to maintain confidence in the system as it proceeds along the development path. The tendency is great for the operator, and others less familiar with the research and development (R&D) process, to pronounce a system less than desirable during early tests; in particular, if some unforeseen incident, or malfunction occurs. It is, therefore, incumbent upon the project manager to assure that an ample slice of the total development effort is applied to safety engineering. This will vary with the system, however, figures of 1 - 7% have been suggested. The AF's MINUTEMAN used about 3% and the Supersonic Transport (SST) will go to about 6%. The Army's PERSHING 1a missile system is running about 1/2%, however, this program is limited to development of new ground support equipment (GSE), the missile having been operational for some time prior to commencement of the project.

CHECK POINTS

The Army policy is implemented in the AMC by assignment of management responsibilities to Headquarters elements, such as our own Safety Division and the Director of Quality Assurance, the Major Commands, Project Managers, and Safety Directors at Commodity Commands, or installations and activities involved in the development and procurement of materiel. In implementation of the basic policy, we have established certain safety check points.

1. Safety Statement. This is a summary of the data collected during design and development phases. Submitted to the project manager, or other designated manager prior to engineering test, it states what hazards still exist and the recommended actions (procedural or otherwise) required to minimize or eliminate them.

2. Safety Release. This is similar to the Safety Statement, however, it is prepared later, after engineering test has been completed. An Interim Release may be made earlier, based on the best judgement at any particular period during engineering test (ET).

3. Aircraft Firing Flight Safety Release.** A summary of safety information based on the Safety of Flight Release and ET ground firings of aircraft armament sub-systems.

4. Safety of Flight Release.** This includes certification that the aircraft is capable of performing as designed, and is in compliance with design criteria, FAA standards, and other required specifications. It also includes the standards outlined in MIL-S-38130A.

5. Safety Confirmation. A statement prepared by the U.S. Army Test and Evaluation Command (USATECOM) which consolidates the findings from ET and service test (ST), indicating the degree to which the item meets safety requirements established by the basic qualitative requirements document under which it was developed.

These check points, or evaluation milestones, appear to produce results. Although it is always difficult to assess the value of a safety program in terms of whether its absence would have resulted in an inferior product, there has been sufficient experience in the past several years to justify the rather modest amounts spent for these programs.

ANALYTICAL TECHNIQUES

The analytical techniques that exist today are variations on methods used for many years, but updated by new symbology, improved mathematical operations, and better presentation. With the advent of computers, many fault producing elements can be explored that were not possible with manual techniques. At the present time, Army development contractors use most of the familiar techniques which I will briefly discuss later. The development agencies within the Army, and production facilities have not adopted any of them extensively, although reliability analysis and computer analysis is used for certain operations. We believe substantial gains in plant safety can be achieved with the use of a technique which would isolate a particular hazardous manufacturing process. Accordingly, this is considered a fruitful area for future effort. In particular, some accidents occurring on ammunition assembly lines might have been prevented if a comprehensive pre-analysis of the operations had been accomplished.

**Responsibility of the U.S. Army Aviation Command, but listed to show the broader aspects of safety considerations within the Army.

Another area of concern is the proliferation of solid state circuitry. It is no longer feasible to preclude operation of a quick reaction system by removing a component and placing it under special security. This method of opening power and signal circuits has been replaced by solid state constant and/or scan monitors which ensure circuit integrity and automatically open or close circuits depending on the soft ware program directing the operation. This, then, introduces the soft ware itself into the same area of concern. For example, during a recent PERSHING test, a missile erection and firing sequence was initiated before the remote firing circuit was energized. Although the capability existed at the remote fire box to terminate the countdown (C/D) manually, this particular problem was serious enough that the "single" manual safety interlock remaining (man at the box) was considered inadequate. The premature erection was actually caused by a relay being set before it was commanded by the soft ware program. (A punched tape). It was a safety problem that could not be detected during analysis of the hardware. Modifications were made to include a monitor on the fire command supply line for a "no signal" condition. The C/D was modified to "loop" until receipt of a signal from a monitor on the relay. The computer will read the monitor for a signal and, if one is present, the C/D will continue. If none exists it indicates a malfunction and a "hold" or "shutdown" will occur.

This example, relatively simple, indicates the magnitude of the problem envisioned in future systems. At present, we have no really good analytical technique to determine ahead of time if the soft ware is free from variations which might create system hazards. As in the case just related, it is possible to determine after an event what occurred, but prior determination of probable "soft ware" deficiencies is not possible. The analytical techniques available for hardware analysis are fairly familiar and four of the most common will be mentioned here in summary only. These examples are among some 25-30 which are available. Undoubtedly there are more, in addition to variations which also take on special significance in special cases.

1. Fault Tree - a method wherein an undesirable event is established for a particular sub-system or system. A pattern of logic symbols is created to trace backwards through the circuits to determine the error paths and specific malfunctions which can either cause them, directly, or in conjunction with other events, to create a hazard.

2. Failure Mode and Effect - This method presumes that every element of a system has a failure mode. The effect of the mode on the next higher element, or component, is determined and after several levels of calculation it can be determined what the system reliability will be. It is the reverse of, and more time consuming than, the Fault Tree Analysis technique.

3. Piece Part Counts - The technique consists of determining the failure rate of every part and establishing reliability numbers from this data. It is the most detailed and time consuming of all the techniques, but is required to support the others in most cases.

4. Design Audit - When a basic design is put on paper, it is analyzed by an independent engineer to determine if it will work as it was designed. Here, one is not too concerned with its failure mode, or whether it will cause hazards, but merely if the design will produce the effect that has been specified. If some potential hazard is uncovered, the audit has been doubly profitable.

5. Safety Studies - These are obviously the culmination of all or parts of 1 through 4 plus consideration of the operational concept and method of employment. The stockpile-to-target sequence and evaluation of the safety of the system through its proposed operational cycle is included.

The best time to integrate safety engineering principles is during the initial design. At this point features can be changed without great expense, because we are dealing with concepts and paper, rather than operating hardware. During the trade studies is the best time to state safety requirements, for they can be considered in the light of time, expense, and complexity more effectively. Often it has been found that inclusion of a safety feature has increased reliability considerably, by eliminating a hazardous area which d have degraded the operation of that equipment.

PROGRAM GUIDELINES

The guidelines we are striving to implement in detail among our safety managers are based on MIL-S-38130A, and other current documentation within the command. They are ranked in general importance, and include those items which each manager can expect to encounter.

1. Safety Requirements. The most important element is establishing system safety requirements. Unless these are properly stated in the basic documentation and detailed in specifications, the equipment designer may be at a loss to know what to avoid, or, to include. Certain guidelines exist, but newer systems require somewhat different approaches.

2. Organization. An organization must exist at major command level to direct and coordinate the effort. Equally important, the lower echelons need well qualified safety engineers to implement the detailed portion. Finally, the contractor must adequately cover the safety area. It will be his decision as to how he discharges the function. We favor the safety management approach, where a small group directs the effort, supplying technical requirements which are then converted into detailed designs and analyzed by appropriate engineers who have the necessary background in the various disciplines of mechanical, electrical, electronic, chemical, nuclear, etc. engineering. This, of course, does not preclude establishment of any kind of organization with the goal of adequate safety engineering, regardless of the methods used.

3. Data Collection. The safety engineer must have data upon which to base his analyses and to further the establishment of requirements. It is not feasible to duplicate data which already exists within other areas, such as reliability, quality control, maintenence engineering, and similar activities. All can share the information; adaptation for special purposes is possible. The sources are not necessarily endless, but come from many activities within the organization, and from vendors of individual components.

4. Work Apportionment. The individual safety manager should not try to do all the detailed work within his own shop. In most cases, he will not have the engineering talent and it appears impractical to hire a large group of engineers to cover every conceivable area. As related to the organizational concept and data collection aspects discussed earlier, he must be provided with the engineering resources and data upon which to base inclusion of safety requirements in any one system, sub-system, or component thereof. Pure analytical work can be best accomplished by those persons who can maintain daily proficiency in it.

5. Safety Testing. Adequate thought must be given to safety features in test programs. Both detailed component and full system tests must have specific safety aspects included. There are several broad areas in which safety can be integrated without imposing unusual broadening of the test scope. In most cases, safety tests will be conducted concurrently with another test, but data collected for safety purposes can

be based on a specific requirement. These are the major areas:

(a) Tests in which a safety feature is checked to determine if it operates to prevent the hazardous event it is designed to eliminate.

(b) Where warnings, or visual/aural signals are used, they must be evaluated to determine if the operator can respond and take corrective action to prevent occurrence of a hazard.

(c) Where safety limits are established, determine what effect excluding these limits will have. Where explosives are involved, special facilities are required and these tests must, of necessity, be limited to very specific areas. Temperature, shock, vibration, etc. are major envioronments which fit these cases.

(d) The possibility of bypassing a safety feature, as opposed to deliberate activation, should be determined. Inadvertent operation and its effect is closely allied to this kind of test.

SUMMARY

In summary, the AMC safety engineering program is designed to assist in fielding operationally effective systems. The list of functions, guidelines and analytical techniques is impressive, but not the final answer. The science of analysis has not advanced as rapidly as some of the other disciplines. At present, the two most pressing problems concern solid state devices and soft ware contemplated in missile systems under development. PERSHING and SENTINEL are prime examples. Of corollary interest, data acquisition is one of the more important areas which causes many an analyst to fail or succeed in his efforts to produce a good product. The lack of it is not always the problem, but the lack of adequate and specific data on performance of a particular item often prevents the production of meaningful probabilities of the occurrence of hazardous events. Where the safety engineer used to be primarily concerned with mechanical devices, rather easily understood, he is now confronted with electronic programmers and other equipment, the functions and failure modes of which are not completely understood even by their designers. In addition, operational reaction times now specified in current tactical firing doctrine preclude reliance on the concept of removable components to achieve safety. All these changes have created the need for an expanding capability to evaluate safety from a more sophisticated level. We must convert from the "hard hat" to the "hardware" concept, with ample emphasis on the "soft ware".

Questions and Answers on Wells' Presentation

1. How would you establish a System Safety organization from scratch and how extensive should it be?

Ans. It would depend to a great deal on just what was your organization, what kind of safety, what kind of funds had been allocated to you, and a dozen other parameters. However, in general, depending upon the size of the parent organization, you should have a director with several safety engineers performing those necessary tasks such as documentation, analysis, testing, reporting and keeping the records straight. If you would follow the plans contained in Mil-S-38130A, you wouldn't be far wrong in setting up a satisfactory program.

2. Some of us have heard that Mil-S-38130A will be replaced by MIL-STD-882 as the System Safety Guide. Do you have information on when this will become effective and what the general difference is?

Ans. The MIL STD is presently in our office in AMC for review and our comments will be included in the near future. Basically, the difference between the two documents is that the MIL STD is a bit more less complicated than the Mil Spec and it contains a fine sample for a safety plan which is not covered as well as in the Mil Spec. It may still take some time for the MIL STD to be approved and distributed.

3. Why cannot the design people handle system safety without the necessity for setting up an expensive system safety organization?

Ans. Design people are a strange breed of cats, and they design things to work. That is their first consideration. Then comes the system safety considerations. If the system safety people are in on the design features by looking over the drawings before the hardware is manufactured, much time is saved and system safety is automatically cranked in. Design personnel do have the know-how for including the general aspects of system safety in their designs, but it takes the safety engineers to check out the specific aspects of system safety.

SYSTEM SAFETY ON A SHORT BUDGET

by

Lawrence C. Montgomery
Jet Propulsion Laboratory
Pasadena, California

Abstract

Spacecraft systems have become most complicated and require the coordination of a multiplicity of disciplines at an advanced "state-of-the-art." For this reason, the achieving of safe systems for spacecraft has also become increasingly difficult and complicated. Budget limitations at the Jet Propulsion Laboratory have required the formation of dynamic system safety practices for each flight project, implemented by the technical organization to assure that a proper safety analysis is made. This paper describes the organization employed and the methodology of its functions to achieve close scrutiny of system safety on a short budget.

Introduction

System safety is not a new activity. Any engineer or group of engineers who has ever designed anything from a stapler to an airplane has considered safety -- to various degrees. (Probably they arrive at their safety position in much the same way as a motorist decides how to drive "safely" on the freeway.) But now, with the increasing complexity of systems in all phases of engineering activity, safety has required new emphasis, and new techniques and new terms are used to help achieve proper emphasis.

Before we look at the overall problem of system safety, let us define some of the pertinent terms:

A hazard is a condition which can cause disability or death to personnel or damage to or loss of equipment or property.

Safety is the activity of minimizing the hazards; system safety is the applying of safety activities to a total system.

System safety is a dynamic term. It emphasizes the fact that all old or new equipment should be considered in terms of its involvement in the total system to achieve the best safety posture. The need for thorough safety evaluation has brought the Jet Propulsion Laboratory to an overall systems approach within the realm of total project activities.

There are several ways of approaching system safety: (1) to allow engineers to exercise their own judgment and coordinate with other parts of the system, as has been done in the past; (2) to charge management with close supervisory control of safety and leave management to its own devices; (3) to form a new team of engineers to evaluate the total product in terms of system safety; or (4) to use a combination of these approaches.

Purposes and Needs

Before we suggest an approach for structuring a safety program, let's first examine the purpose and need for such a program.

The purpose of the program is to examine in detail the potential hazards and control of the hazards of the overall system and to determine how each part of the system affects the safety of any other part of the system, and relates to the whole.

The needs for such a program are: (1) to identify all possible hazards for a system, (2) to analyze the overall safety of each item regarding the possible hazards, (3) to examine how any subsystem output, intentional or spurious, might affect any hazard in the system, (or possibly combine to create a hazard); and (4) to determine how to eliminate or control the hazards.

The identification of hazards and setting of requirements for their elimination or control must be a continuing function from the initiation of any project. The earlier these items are determined, the easier the correction or control will be. To do this, the program needs to: (1) obtain people who know (or can understand) the subsystem and system in detail, (2) require of them a careful and complete examination of the subsystem and system for hazards, (3) require a recommended resolution of the possible hazards or establish protective requirements, and (4) ascertain that all needs or requirements are met.

To be effective in these functions, the safety program must have the necessary authority to accomplish its objectives.

Methodology

The first approach to safety management mentioned above (letting the engineers take care of safety) involves two problems: (1) the engineer may not see or take time to determine the overall system effect on hazards of his design, and (2) engineers tend to over-rate the capabilities and safety of their engineering jobs.

The second method of approaching system safety is to have management supervise safety. This is a standard and reasonable approach to safety

with two possible weaknesses: (1) management often is busy with other affairs and is pressed for time and resorts to "having faith" that the engineers will take care of it ("It's a normal engineering function") and (2) subsystem management often takes a very parochial view and forgets about its interfaces with other systems. (This attitude prevails: "I'll tell them about my outputs. It is up to others to "shield" against any effects.") This is particularly true with subcontractors furnishing subsystems to "performance specifications." ("We are here to make a profit. Others will have to take care of their own problems.")

The third type of approach (appointing a group of experts) can be successful but is extremely expensive. First the group of "experts" have to "re-do" and become completely familiar with all designs of the subsystems in detail. This kind of expert is hard to recruit into the safety field, away from system design; it will take money. Also, a close examination of this degree, should already have been done by the systems engineer, so we have a duplication of effort. A third, very drastic problem with this safety approach is that engineers and system designers may become sloppy from a safety standpoint, expecting that the "experts" will find any problems they overlook. They may even have contempt for someone else doing their job -- not a healty situation.

At JPL we use a combination of these approaches in very measured quantities, implemented through a Safety Steering Committee. This procedure hopefully incorporates the best from each of the approaches named at a maximum effectiveness for a minimum cost. The elements are the engineers, the subsystem supervisors, the system management, and a flight project safety engineer. The supervisors, system management, and flight project safety engineer are constituted into the Safety Steering Committee, which forms the central safety emphasis and safety communication link to all subsystem and system parts. This committee is delegated the total responsibility of fulfilling the needs of the safety program as given on the preceding page.

The safety engineer's responsibility is to train the committee members in safety analysis; establish proper safety emphasis; make a separate, independent assessment of subsystem, system, and project safety; and act as a consultant to the committee on safety matters. He also furnishes the authority to assure proper safety emphasis.

The system management representative makes an assessment of total system safety, determines the effect of safety needs on system performance, schedule and cost, and evaluates the effect of system changes on safety.

The subsystem supervisor is responsible for the following: (1) informing subsystem engineers of safety constraints, (2) working with the engineer to assure that a proper design is provided, (3) assuring that a proper design is provided, (3) assuring that a proper safety analysis of the subsystem is made, (4) generating the subsystem part of the hazard

catalogue, (5) evaluating with other committee members the interface effects of all subsystems on the identified hazards, (6) feeding-back necessary changes to the design engineer, (7) keeping the committee informed of the safety status of all subsystem or interface safety problems, (8) supervising the preparation of operational documents to assure the inclusion of proper safety requirements, (9) supervising the preparation of necessary safety reports, and (10) acting as a consultant on his subsystem.

The subsystem engineer is responsible for ensuring that proper safety constraints are met by his design, preparing safety reports for the supervisor, and making the required changes.

This system has many advantages, some of which are:

(1) Independent evaluations of primary safety concerns by supervisory management, system management, and safety engineer catalyzes better safety performance and assures a more positive safety treatment,

(2) Prime responsibility for identification and control of hazards remains with the subsystem engineer and his supervisors--the experts, (they will catch and correct most of their own safety errors without the anguish of outside pressure),

(3) The supervisor becomes thoroughly familiar with his subsystem and makes a safety assessment with the engineer,

(4) The supervisor evaluates his engineer on his safety performance, which gives added safety incentive,

(5) All supervisors are made aware of all known hazards,

(6) The committee members make independent assessments of other subsystems and interface areas,

(7) It is easier to evaluate the interface safety effects by the coordinated efforts of the subsystem supervisors,

(8) The system manager is made aware early of the subsystem safety status and can make an independent assessment of the safety of the system,

(9) System management can better evaluate the effect of changes on system safety,

(10) Regular assessment of safety is required by safety policy and, therefore, it is not relegated to the "back seat,"

(11) A safety emphasis permeates the organization in a cooperative effort,

(12) Clear lines of communication on safety problems are established throughout the system,

(13) The safety engineer has a specific communication system through which to gather information for assessment of safety criteria and requirements.

The scheduled meetings and requirements for safety status reporting by the committee are catalytic forces for total hazard evaluation and correction. The engineer and his supervisor are given aid by other supervisors, system management, and safety engineers in doing their normal safety job more thoroughly, system-wise.

Conclusion

The Safety Steering Committee approach has been used in the Mariner programs at JPL and is being employed now on all JPL projects. The safety emphasis filters to all parts of the system organization and catalyzes a strong safety effort. All elements of the Safety Steering Committee have contributed individually, as well as collectively, to the Mariner '67 success and have already affected the safety status of the Mariner '69 program.

This system safety program assigns the major safety emphasis with the experts, who are already responsible for the design integrity. It requires guidance from a safety engineer in the top management and system management offices. It requires an attentiveness to safety items throughout a system without a large mobilization of additional personnel with associated costs. By functioning from the beginning of the project, the Safety Steering Committee system appears to achieve a maximum degree of safety evaluation and correction or control on a minimum amount of money, and that is the "oooonly way to fly."

Questions and Answers on Montgomery's Presentation

1. Did you have a budgetary ranking system for a comparison of your four ways of approaching system safety at JPL?

Ans. Yes, an analysis was made of the various approaches and it was determined that the combination of management, expertism, and ideas from engineers all combined to satisfy the system safety needs at a minimum cost.

2. Has the JPL Safety Steering Committee philosophy been established by management edict, a trial and error method over a period of time, or by a programmed growth type of approach?

Ans. To start with, no one likes the committee approach, so a safety group was set up. By experimenting over a period of time and watching our costs, a normal growth took place which finally culminated in the less inocuous name of a steering committee. This method seems to work best for us.

3. What are the dimensions of the Mariner device you will be launching in the near future?

Ans. It will measure about fourteen feet tall by about twelve feet across, and it would fit comfortably in this room.

4. Other aerospace teams, notably, Boeing, Bendix, and North American have established the so-called "expert" type of system safety organizations. Is this a really good practice in your opinion?

Ans. Any system safety organization composed of experts and top-heavy administration could be expensive. I don't know just how these safety groups are set up, but I'm sure the steering committee method is more economical.

5. In the Voyager and Mariner programs, it seems that reliability is more important than safety. Can you comment on this aspect of sending vehicles into outer space?

Ans. Reliability must be considered in designing for performance in outer space just as System Safety must. These two disciplines go hand-in-hand; however, there are some cases in which if reliability only were considered, the item might be so reliable that it would be unsafe, and vice versa. Reliability considers the need for high performance; system safety considers the treatment of hazards, real or potential, which might detract from high reliability.

TITAN III DESTRUCT SYSTEM

by

Neil C. Spencer
Pan American World Airways, Inc.
Cape Kennedy Air Force Station
Florida

Because errant missiles with tons of TNT equivalent explosive capability can pack a highly destructive punch, a reliable, redundant destruct system for the protection of the launch crew and the general public is installed in all major vehicles launched on the national ranges. On the Titan IIIC this system comprises (1) a command destruct capability and (2) an inadvertent separation destruct mechanism. Both mechanisms operate through a common safe/arm device.

Two identical redundant destruct systems are used on the Titan IIIC for the solid and liquid motors. Although these systems are somewhat different in design their function is the same; that is, to rupture the propellant container thereby effectively resulting in destruction of the vehicle. This is accomplished in the core by wafer-shape charges between each set of tanks. These charges are positioned in such a manner as to rupture the tanks and allow mixing and burning of the propellants. They can be initiated either by a command destruct signal or by an inadvertent separation of the air frame. Each stage of the core has its own safety and arming device independent of any other. On the solid motors a linear shaped charge is the rupturing agent and this opens a thrust termination port and splits the casing of each solid segment effectively destroying the motor function.

The Command Destruct System receives, and responds to, ground originated commands from the Range Missile Control Officer. These commands may be for thrust termination only by cutting off the flow of propellants to all engines, or for thrust termination followed by vehicle destruct.

An inadvertent separation destruct system (ISDS) is incorporated in Stages I and II of the core vehicle to automatically destroy the stage should the air frame separate. Each stage has its own power supply to provide destruct power in the event of break-up.

The Solid Rocket Motor Flight Termination System consists of a thrust termination system and a destruct system. Both use the same safe and arm device and ordnance devices. These ordnance devices are a transfer harness, linear shaped charge, and jumper harness. They respond to core-generated commands or self-generated signals in case of inadvertent separation.

The power for command destruct and thrust termination preceding command destruct is supplied from the core vehicle. The functioning time from receipt of detonator output from the S/A to initial severing of the first segment is 480 micro-seconds. Total time to sever the five segments is approximately 2.5 milliseconds. Reliability of the explosive train is required to be 99.5% at a confidence level of 95%.

The ISDS on the solid motors is a "hot wire" system. Its activation requires the breaking of redundant hot wires and redundant safety ground wires between the SRM and the core.

The primary function of the ISDS is to activate thrust termination and destruct, with appropriate delay, in the event that command link is lost due to premature separation of the solids from the core vehicle. In addition, the ISDS serves as an electronic safety block for the staging moto s and monitors the fire command circuits of the S/A devices for hazardous currents while the vehicle is in a prelaunch condition. Before staging motors are fired to separate the SRM's from the core the ISDS is disabled.

Thrust is terminated in the SRM by blowing out two 33" port hole covers in the nose section of the engine thus allowing motor combustion gases to escape. These ports are situated 90° from the core on a 180° centerline. Redundant linear shaped charges of RDX each containing 300 grains per foot and the detonators are installed by T-200 minutes in the countdown procedure. The system is armed at T-9 seconds.

The destruct system is installed at the same time as the thrust termination ordnance and consists of:

1. A Safe and Arm device in the nose fairing structure.

2. A redundant transfer fuze servicing two linear explosive charges.

3. Redundant linear shaped destruct charges located within a raceway extending the length of each solid motor segment.

4. Destruct jumper fuzes.

The S/A device provides a means for remote arming and safing and a means for electrically monitoring the S/A position. With the S/A device in the safe position, the circuit between the firing leads and the detonators is open, and the detonators are shunted. Arming of the S/A device establishes continuity between the firing circuit and the detonators and removes the shunt across the detonators.

The S/A device also contains a means for checking or monitoring the firing circuit at full current without firing the detonators while the S/A device

is in the safe position. The S/A device also has a manual safing provision which does not allow manual arming but which allows manual safing of the S/A device with the rotor in any position. The design of the manual safing position is such that the S/A device is manually safed without going through the armed position.

With the S/A device in the safe position, inadvertent ignition of the detonators will not result in propagation of the entire explosive train. In the event that inadvertent ignition of the detonators does occur while the S/A device is in the safe position, the linear shaped charges will not be detonated. The S/A device has a mechanical safety pin which prevents it from being armed. This pin must be removed to arm the device and is retained by Pad Safety as physical evidence that the device is capable of being armed. It cannot be removed if arming voltage is present.

Before any ordnance is installed in the vehicle Pad Safety obtains possession of the keys to the Flight Safety console and the Instrumentation Van so inadvertent arming of the destruct circuitry can not take place during installation. Only then will Pad Safety grant permission to proceed.

Detonators are installed within the S/A devices to provide a shock wave capable of detonating the transfer fuzes in the explosive harness. The recommended firing current is 4.5 amp minimum with a function time of 4 milliseconds or less.

For safety purposes, of course, all ordnance must meet the 1 amp - 1 watt no-fire requirement of Air Force Safety.

The Destruct Transfer Fuze is comprised of two redundant cores of 70 grains per foot RDX with appropriate explosive crossovers for additional reliability. The fuze receives the detonator output and transfers the explosive stimulus to the Linear Shaped Charge. Propagation of the explosive stimulus is approximately 7600 meters per second.

The Linear Shaped Charge provides the explosive force required to sever the motor case and allow the built-up pressure to complete the destruction. The LSC is comprised of 600 grains per foot RDX core enclosed in a seamless copper sheath. Two redundant LSC's are used and secured in a raceway mounted on the motor case.

The Destruct Jumper Fuze is identical in design concept to the transfer fuze and is employed to propagate the explosive stimulus between segments. It is composed of a 70 grains-per-foot RDX core, a flexible cover, boosters at each end, and quick disconnect connectors.

Now the core destruct ordnance is somewhat different. It consists of an explosive bi-directional wafer charge attached to the opposite end of

each of two Primacord fuses originating at the core S/A device. These bi-directional wafer charges are placed between propellant tanks in each stage of the Core Vehicle to achieve propellant intermixing. One wafer charge is sufficient to produce the required destruct action; the other charge is used for redundancy.

Each destruct charge consists of an aluminum container wafer enclosed in an aluminum plate for mounting purposes. The explosive charge consists of PETN sandwiched between lead plates. Two Primacord booster collets spaced 120 degrees apart are contained in each charge.

The total ordnance installation per stage consists of the Destruct S/A device, the necessary runs of Primacord with crimp-on boosters, and two bi-directional wafer charges. In Stage I the device is mounted on the forward dome of the fuel tank. One strand of 100 grains per foot PETN Primacord is inserted in each of the two collets. Crimp-on boosters are fastened to the ends of each strand before insertion in the charge and the S/A device. A separate run of Primacord (with crimp-on boosters) connects the two wafer charges. This constitutes a completely redundant explosive system. If any portion of this system - from the destruct output of either one of the Command Receivers to the end wafer charge - should malfunction, the other portion would perform the destruct function. When the charges detonate, the explosive force opens a large hole in the bottom of the oxidizer tank dome above and the top of the fuel tank below.

On Stage II the mechanism is the same, but the installation is mounted on the equipment truss between tanks.

The Transtage destruct components are identical to Stages I and II. However, since the fuel and oxidizer tanks are mounted side-by-side the wafer charges are bolted to a mounting plate directly between the two tanks with the charges one above the other.

Once the liquid propellant tanks have been filled on the vehicle the area around the launch pad is cleared of all but essential workers to a radial distance of 5000 feet. The destruct system is installed after tanking has been completed. As the countdown progresses toward launch the danger area is eventually cleared of all personnel to 8000 feet.

This, then, is the system that is used to protect launch area personnel and the general public against potential malfunctions of the flight system. The missile control officer has definite guidelines within which the vehicle must remain during the powered portion of its flight. If it strays outside these guidelines, he immediately exercises the Command transmitters either to terminate thrust or to arm and destroy. If structural failure occurs and the air frame breaks apart, the Inadvertent Separation Destruct System will function and destroy the vehicle. All systems are redundant with a required reliability of 99.5%.

Questions and Answers on Spencer's Presentation

1. What is the past performance history on TITAN III?

Ans. The TITAN III has had a very successful career as a vehicle for delivery of small payloads into orbit. Some twelve TITANs have been sequentially successful to date.

2. We have heard that TITAN III has been a booster workhorse for the space program. Is there still a bright future for this program or has it been completed?

Ans. The program is still operating to the best of my knowledge; in fact there will be another two launches prior to the first of the year. It seems to have a very bright future because of its outstanding performance to date.

3. Just for information, and to indicate the importance of system safety, can you give us a quick rundown on TITAN III payloads?

Ans. TITAN has placed many types of payloads in orbit. Most of these have been smaller items like communications satellites, scientific research satellites and the like, but astronaut nose cones have also been successfully orbited. TITAN III reliability has been most outstanding, and this is partially due to the system safety engineered into it.

4. With 33" port hole covers to be blown out in the nose section of the engine to terminate thrust, what is the thickness of this metal?

Ans. I do not know that answer, but in the future it is planned to use other methods for terminating thrust.

5. How is the TITAN III destroyed so that parts will not fall on populated areas?

Ans. (By the use of viewgraphs, the Range Safety Officer's responsibilities were explained, and it was shown how missiles were destructed at flight times projected so that debris would fall within well-defined guidelines.)

FIRE EXTINGUISHMENT AND CONTROL SYSTEMS

FOR PRODUCTION OPERATIONS

Moderator: W. E. Carper
Safety Director, Naval Ammunition Depot
Crane, Indiana

FIRE EXTINGUISHMENT AND CONTROL SYSTEMS FOR PRODUCTION OPERATIONS

SUMMARY

The session was opened by the moderator with a brief explanation of the purpose of the session and manner in which it was to be conducted.

The first topic "Fire Extinguishment Tests on MK 24 APF Compositions" was presented as follows:

a. Previously, tests were conducted at USNAD Crane on extinguishment of Magnesium/Sodium Nitrate flares. These tests were successful in developing a method and means of rapidly extinguishing these flare candles which were previously thought to be uncontrollable. These tests were conducted on single candles.

b. An extension of this program into the production environment involving the loose Magnesium Sodium Nitrate material in a mixing configuration was conducted to determine the feasibility of control and extinguishment of fires in mixers. Various types and configurations of fixed extinguishment devices were used to determine the most effective type. Delay times from times of ignition to time of water application were also varied and effects on temperature were recorded. Various types of materials (aluminum, brass) and various types of safety equipments were placed in the test structure to determine heat effects and degree of protection achieved.

A film was shown illustrating the tests conducted and the results of each.

Conclusions of the tests - that magnesium flare compositions in mix configurations can be controlled by properly designed extinguishing systems - were presented to the session. A general discussion regarding particulars of water pressure, head design, layout design, and time factors was conducted.

The second topic "Liquid Explosive Detonation Traps" was presented by Dr. Charles Dale, NOS Indian Head, Md. Dr. Dale discussed the various types of traps including: Critical Diameter, Precompresssion, Dead Wall, Diameter Transition, Aquarium, Line Severing, Externally Activated, and discussed the principles of operation of each type.

General discussion was held with the participants regarding the principle of traps and their reliability.

A recent NG explosion which occurred at NOS Indian Head was also discussed including possible causes and cures. The design of liquid transfer lines was explored and discussed.

FIRE EXTINGUISHMENT TESTS ON MK 24 APF COMPOSITIONS*

by

W. E. Carper
Naval Ammunition Depot
Crane, Indiana

Preface

A series of fourteen tests (ten, using 125 lbs loose Mk 24 APF Mix, consisting of 58% magnesium, 38% Sodium Nitrate, and 4% Styrene Monomer Binder; one, using 60 lbs granular magnesium; and three, using 54 bare Mk 24 APF Candles) were conducted at U. S. Naval Ammunition Depot, Crane, Indiana. In tests 1 thru 11 the loose pyrotechnic mix was placed in an open steel bowl. In tests 12 thru 14, 54 bare Mk 24 candles were placed on end in a brass cart box.

A variety of automatic sprinkler and spray nozzle water application systems were used. The time before water application was varied.

Test results indicate that extinguishment and/or control of both loose Mk 24 APF Composition and bare-candle fires in production and storage situations is possible. Further testing is required to determine optimum water application rates, pattern of application and speed of application.

Purpose

To determine if control and/or extinguishment of Mk 24 APF composition fires in a mixer configuration could be achieved and to determine if a fire involving a cart load (54) of bare Mk 24 APF candles could be extinguished and/or controlled.

To establish test parameters for water application methods, rates and timing for future tests.

* NAD Crane Technical Report No. NADC-SA-11320/8050-1

TEST FACILITIES AND EQUIPMENT

Test Shelter. A 10' x 10' x 8' high transite on 1" angle iron frame test shelter was erected at the demolition area to roughly duplicate the conditions of a cell. (See Figures 0.1 and 0.2).

Test Mixer. A 39" diameter by 10" deep, 1/4" thick, steel bowl with a flat bottom. A mixer was set on three hollow concrete block piers (32" high) to simulate installation conditions. (See Figures 0.1 and 0.2).

Water Supply - Piping. A 2 1/2" riser, 7 1/2' high, with a quick opening valve and fire department hose fitting, was used to supply the branch lines. The branch lines were varied during the tests to meet the requirements of the various systems used. One or two 2 1/2" lined fire hoses were used to supply the riser through a wye connection from one or two 500 gpm Navy Fire Pumpers. During part of the tests, a 1200 gallon, two compartment, water tank truck was used as a basic supply. (See Figures 0.1 and 0.2).

Nozzles - Sprinklers. Grinnel "Quartzoid" Issue D, 135° sprinkler heads, Automatic Sprinkler Corporation, Fire Fog (Sprayco) Model 6610H spray nozzles with a 75° spray angle and Automatic Sprinkler Corporation "Pilotex", wet pilot sprinklers and special attachments with an ultra-violet flame detector in an explosion-proof housing were used.

Heat Detection - Fire Effects. During tests 5 thru 10, four thermocouples were installed at heights of 6'(#1), 3'(#2), 4'(#3) and 2 1/2'(#4). (See Figures 0.1 and 0.2). During tests 1 thru 5, various materials such as flame resistant coveralls, face shields, gloves, aluminized aprons, aluminized suit, 1/8" thick aluminum and brass sheets of varying dimensions and fiberglass pipe insulation were placed in the shelter to determine the heat effects and degree of protection achieved.

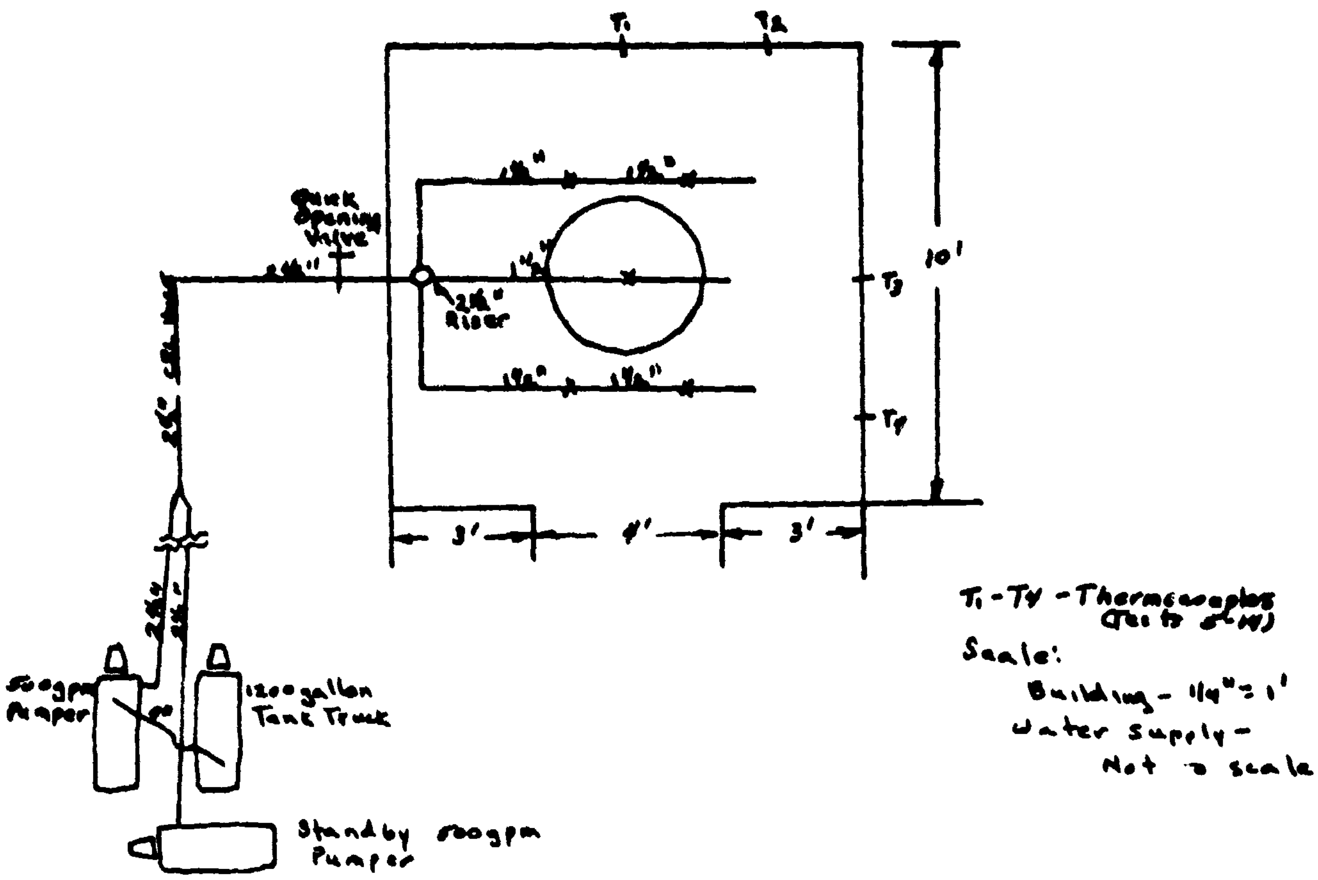


Figure 0.1

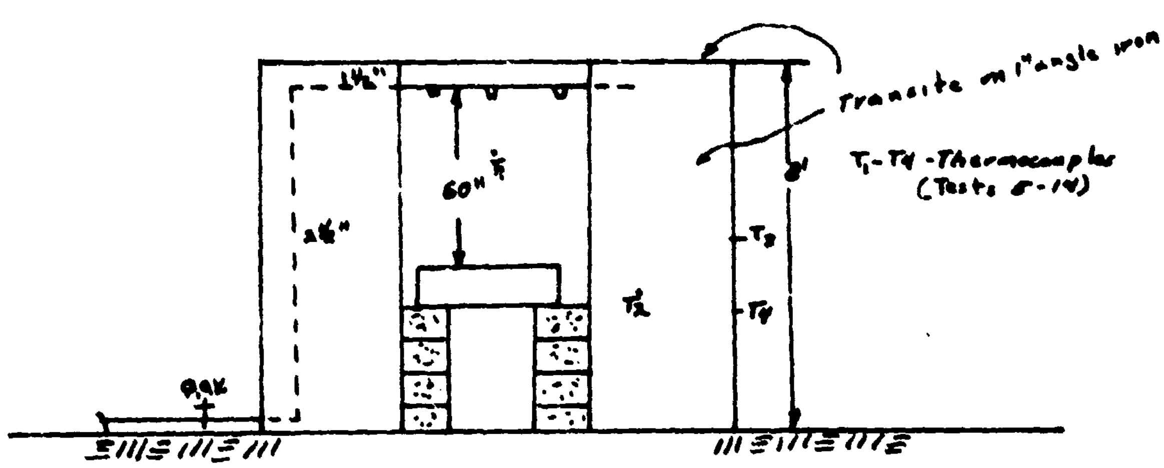


Figure 0.2 Scale: 1/4" = 1'

TEST DESCRIPTION

1. TEST #1

a. One batch (125 lbs) of premixed Mk 24 APF composition was placed in the mixer. Five "Grinnel Quartzoid" 135° sprinkler heads were placed over the mixer. (See Figure 0.1 and 0.2).

b. Water was supplied from the booster tank of one 500 gpm pumper through 300 feet of 2 1/2" lined fire hose.

c. The composition was ignited with two Mk 100 squibs placed opposite each other at the sides of the mixer.

d. Coveralls, face-shield, gloves, fiberglass insulation, aluminized suit, aluminized aprons, brass and aluminum were placed in the shelter. (See Photos 1.1 - 1.8).

Delay time before water was applied	1.5 secs.
Burning time	22 secs.
Pump pressure	100 psi

Condition of materials in test shelter - badly charred - brass softened and fell - aluminum slightly distorted.

Explosion	No
Composition extinguished	No

Observations: Long delay time allowed full fire ball development with consequent high temperatures.

Photo 1.1 - Coveralls, face shield and aluminized suit before Test #1

Photo 1.2 - Coveralls, face shield and aluminized suit after Test #1. Note: Aluminized suit was almost totally destroyed.

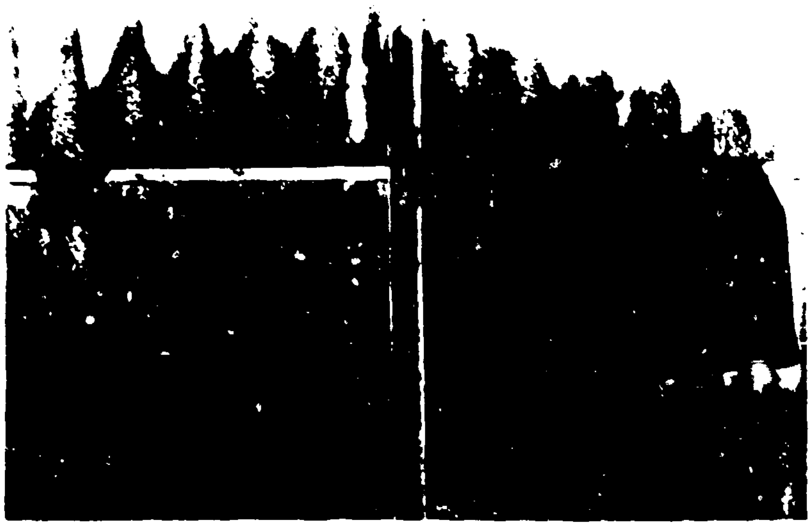


Photo 1.3 - Gloves and aluminized apron after Test #1.
Note: Charred front of apron.

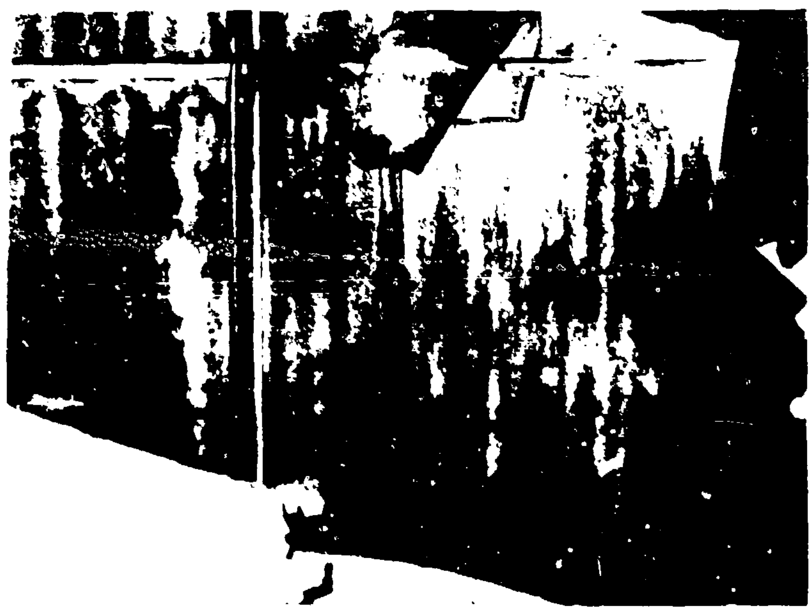


Photo 1.4 - Underside of apron shown in Photo 1.3.
Note: Protected side of apron is not charred.

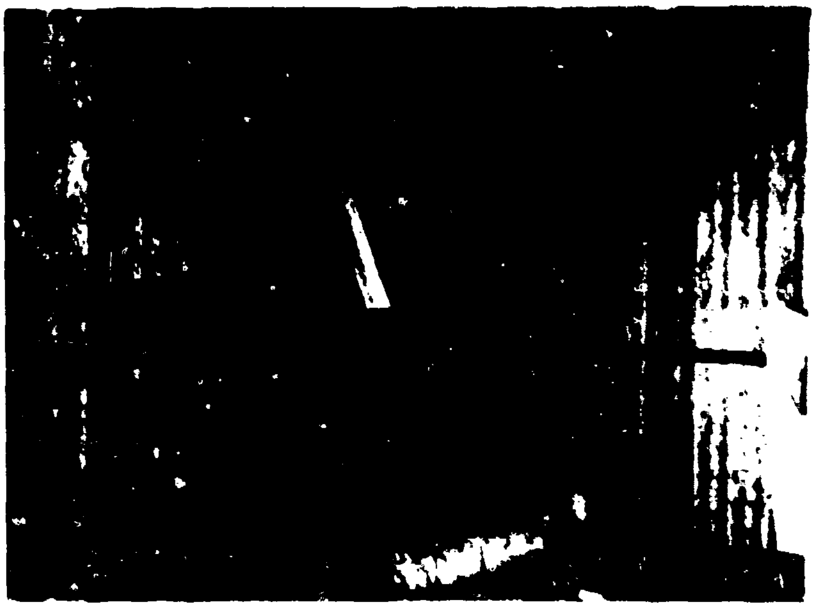


Photo 1.5 - Aluminized sheet and fiberglass pipe insulation before Test #1

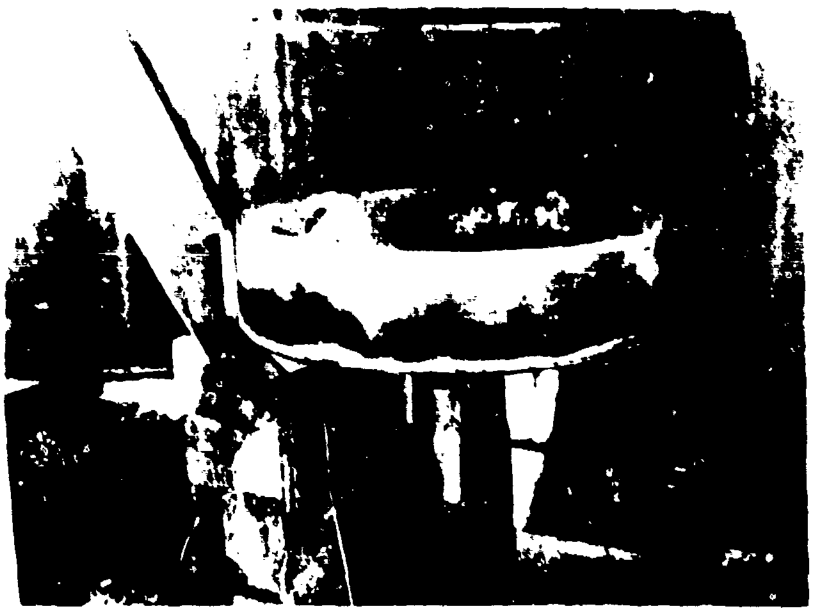


Photo 1.6 - Aluminized sheet only slightly distorted - fiberglass insulation almost totally consumed after Test #1.

Photo 1.7 - Brass sheet, 1/8" thick, softened and fell from angle iron roof supports during Test #1. Note: Brass was partially consumed by fire.

Photo 1.8 - Coveralls on floor adjacent to mixer and magazine thermometer under coveralls both destroyed by fire in Test #1.

2. TEST #2:

a. One batch (125 lbs) of premixed Mk 24 APF composition was placed in the mixer. Five "Automatic Pilotex" wet pilot operated sprinkler heads were installed with an explosion-proof, ultraviolet flame detector.

b. Water was supplied from the booster tanks of two 500 gpm Navy pumpers through two 2 1/2" lined fire hose and a wye connection. There were two 50' sections of fire hose - a wye connection and then 100' of fire hose to the fixed piping.

c. The composition was ignited with two Mk 100 squibs as in Test #1.

d. Coveralls, face shield, gloves, fiberglass insulation, aluminized aprons, 135° Grinnel Quartzoid heads, brass and aluminum were placed in the test shelter. (See photos 2.1 - 2.8)

Delay time before water was applied	50 millisec.
Burning time	12 secs
Pump pressure	120 psi

e. Condition of materials in test shelter - two pairs of coveralls were blown out of the shelter - all other materials badly charred - metals deformed.

f. Explosion - yes, moved test shelter about three feet.

g. Composition was not extinguished.

h. Observations: Rapid application of water with a low velocity spray can allow water to reach hot composition in quantities sufficient to generate hydrogen gas, but not sufficient to extinguish the fire.

PHOTO LAYOUT - Sheet 5

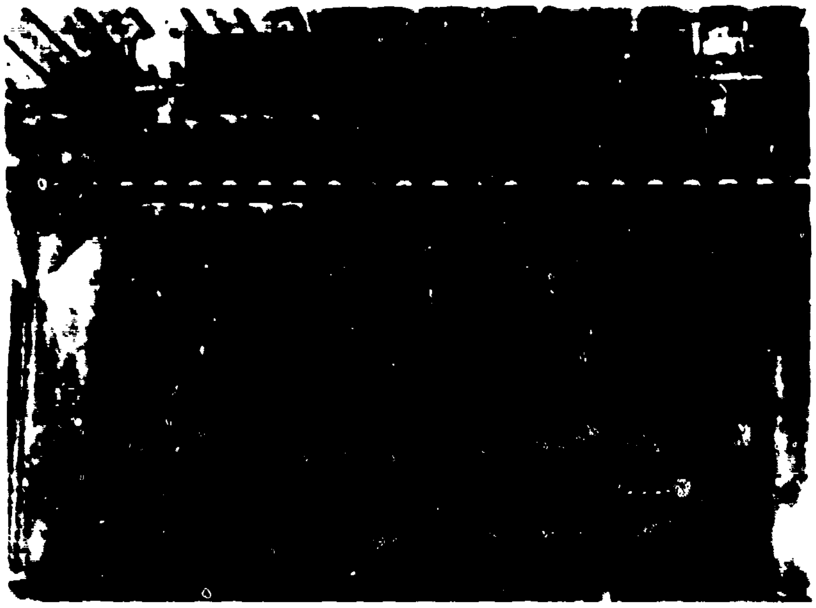
Photo 2.1 - Coveralls, face shield, aprons and gloves before Test #2

Photo 2.2 - Note: Coveralls were blown approximately 25 and 50 feet from test shelter by explosion.

PHOTO LAYOUT - Sheet 6

Photo 2.3 - Fiberglass pipe insulation was used to protect wiring of ultra-violet light detector.

Photo 2.4 - Note: Fiberglass pipe instulation badly charred, but wiring did not fail. Quartz lens on detector was damaged.



2.5 - Wet pilot "Pilotex" sprinkler system centered over mixer before Test #2

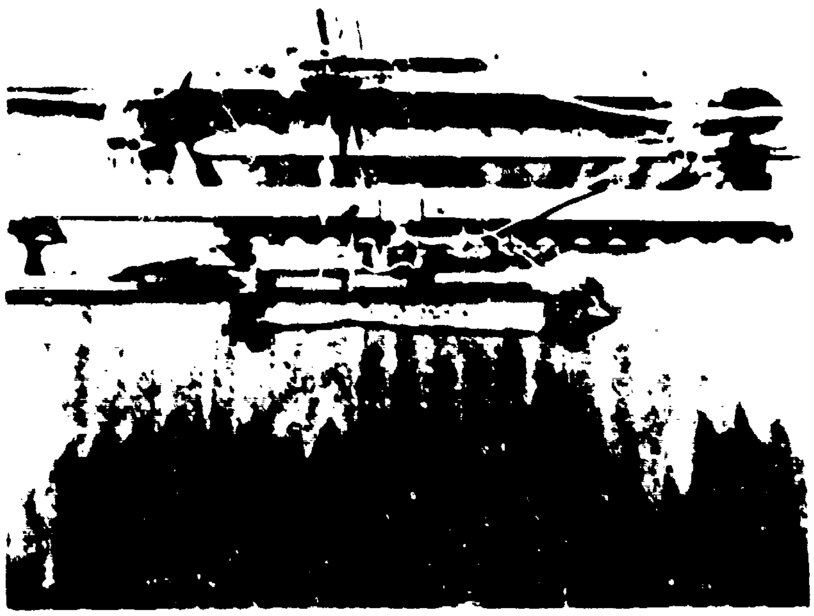


Photo 2.6 - Note: Two front sprinklers and pilot line partially consumed by fire after explosion moved test shelter.

Photo 2.7 - Aluminum sheet, 1/8" thick, before Test #2

Photo 2.8 - Aluminum sheet badly distorted after Test #2

3. TEST #3

a. One batch (125 lbs) of premixed Mk 24 APF composition was placed in the mixer. Five "Grinnel Quartzoid" 135° sprinkler heads were installed as in Test #1. (See Figures 0.1 and 0.2).

b. Water was supplied from two 500 gpm Navy pumpers through two 2 1/2" lined fire hoses 50' long to a wye connection and then through 100' of 2 1/2" lined fire hose to the fixed piping.

c. The composition was ignited as in tests #1 and #2.

d. Coveralls, gloves, aluminized aprons, aluminum and brass were placed in the test shelter. (See photo 3.1 - 3.5).

Delay time before water was applied	1.5 secs.
Burning time	22 secs.
Pump pressure	100 psi

e. Condition of materials in test shelter - badly charred - aluminum sheet burnt - brass deformed.

f. Explosion - yes, but did not move shelter.

g. Composition extinguished - no.

h. Observations: Low velocity water applications even with long delay times (1.5 seconds compared with 50 milliseconds in test #2) can result in hydrogen production and explosions.

Photo 3.1 - Grinnel "Quartzoid" 135°F. head sprinkler system centered over mixer before Test #3

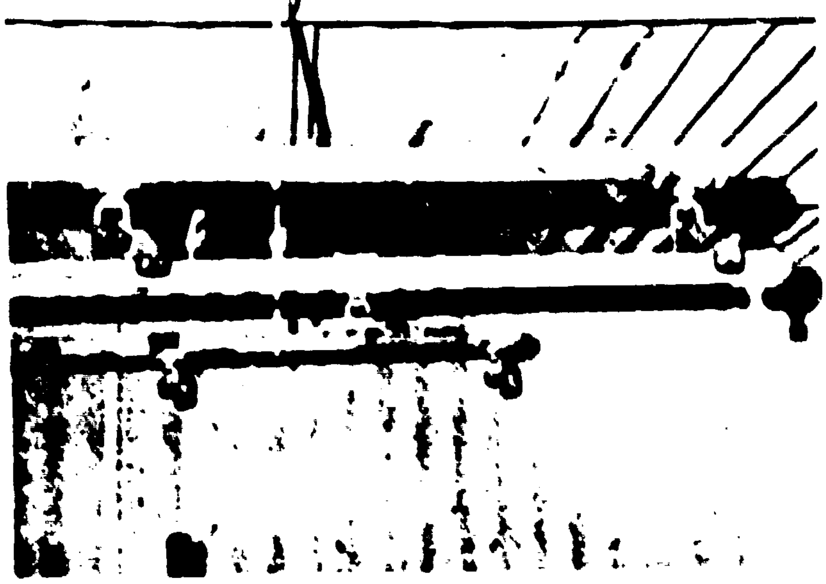


Photo 3.2 - Sprinkler heads after Test #3. Note: Center head partially consumed by fire.

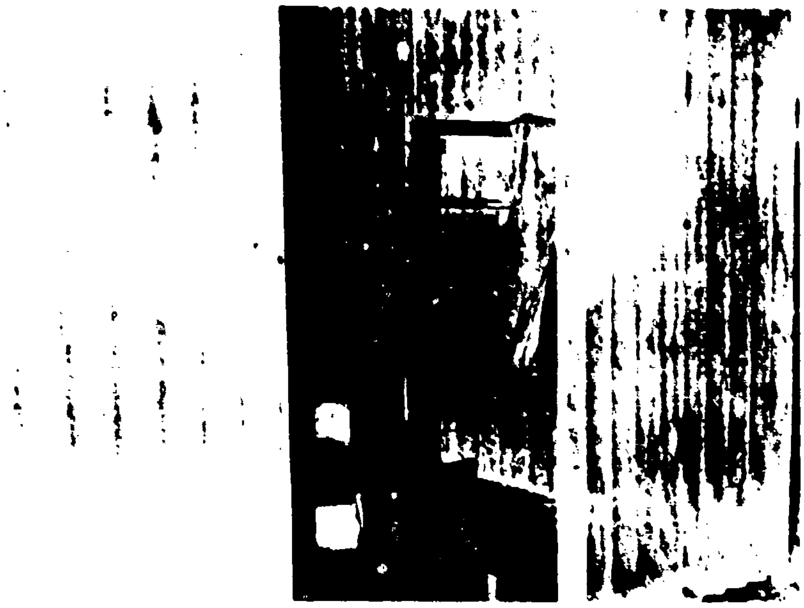


Photo 3.3 - Coveralls before Test #3

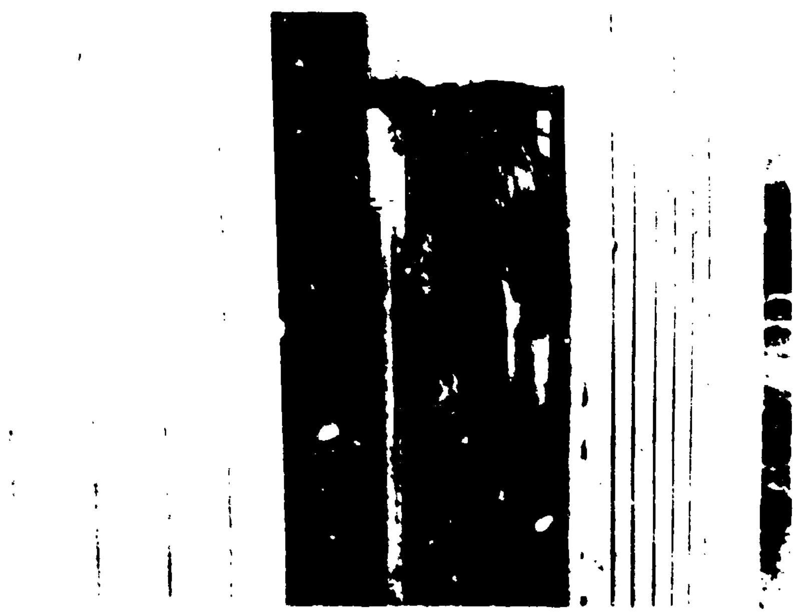


Photo 3.4 - Coveralls after Test #3

PHOTO LAYOUT - Sheet 11

Photo 3.5 - Aluminum Sheet (1/8" thick) before Test #3

Photo 3.6 - Almost half of aluminum sheet was consumed by fire in Test #3

4. TEST #4

a. One batch (125 lbs) Mk 24 APF composition was placed in the mixer. Five "Grinnel Quartzoid" 135° sprinkler heads were placed over the mixer as in Tests #1 and #2. (See Figures 0.1 and 0.2).

b. Water was supplied from one 500 gpm Navy pumper taking suction from a two compartment 1200 gallon water tanker through 150' of 2 1/2" lined fire hose to the fixed piping.

c. The composition was ignited as in Tests #1, #2, and #3.

d. Coveralls, aluminized apron, aluminum and brass were placed in the test shelter. (See photo 4.1 - 4.5).

Delay time before water was applied	1.5 secs.
Burning time	12 secs.
Pump pressure	90 psi

e. Condition of materials in test shelter - badly charred, burnt - aluminum slightly deformed - brass unaffected.

f. Explosion - Yes, moved test shelter about 4 feet.

g. Composition extinguished - No.

h. Observations: See Test #3 observations.

Photo 4.1 - Sprinkler system and brass sheet before Test #4

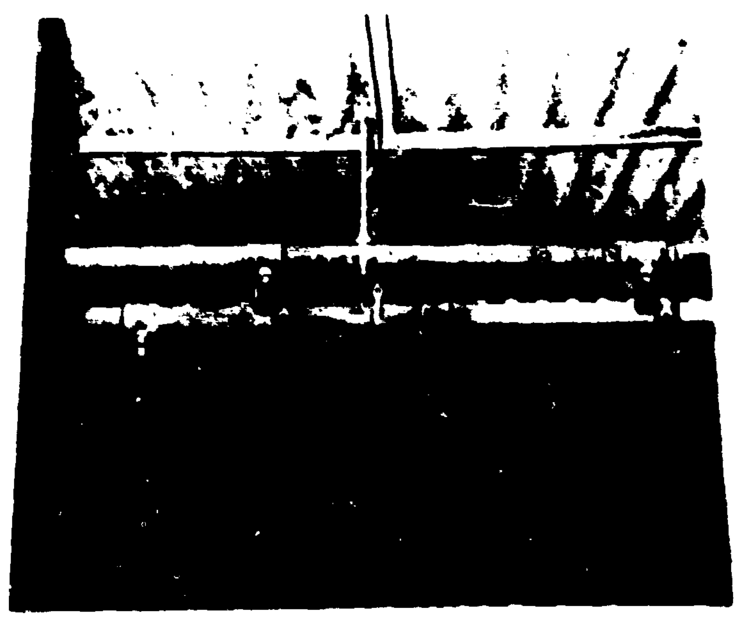


Photo 4.2 - Sprinkler system and brass sheet after Test #4

Photo 4.3 - Coveralls on ground adjacent to mixer before Test #4

Photo 4.4 - Coveralls badly charred after Test #4

PHOTO LAYOUT - Sheet 14

Photo 4.5 - Note: Force of explosion moved test shelter about 4 feet.

5. TEST #5

a. One batch (125 lb) Mk 24 APF composition was placed in the mixer. Two "Sprayco" 6610H, Automatic Sprinkler Corporation spray nozzles were positioned directly over the mixer. (See photo 5.1).

b. Water was supplied by a 500 gpm Navy pumper taking suction from a 1200 gallon tank truck. A 150' long 2 1/2" fire hose supply was used to the fixod piping. The quick opening valve was manually operated by a long rope.

c. The composition was ignited as in Tests #1 - 4.

d. Four thermocouples were placed in the walls of the test shelter. (See Figure 0.1 and 0.2).

Delay time before water was applied	1 sec
Burning time	2.5 secs
Pump pressure	110 psi

e. Thermocouples #1 Max Reading 2100°F - 1.8 secs

#2 Max Reading 2250°F - 1.7 secs

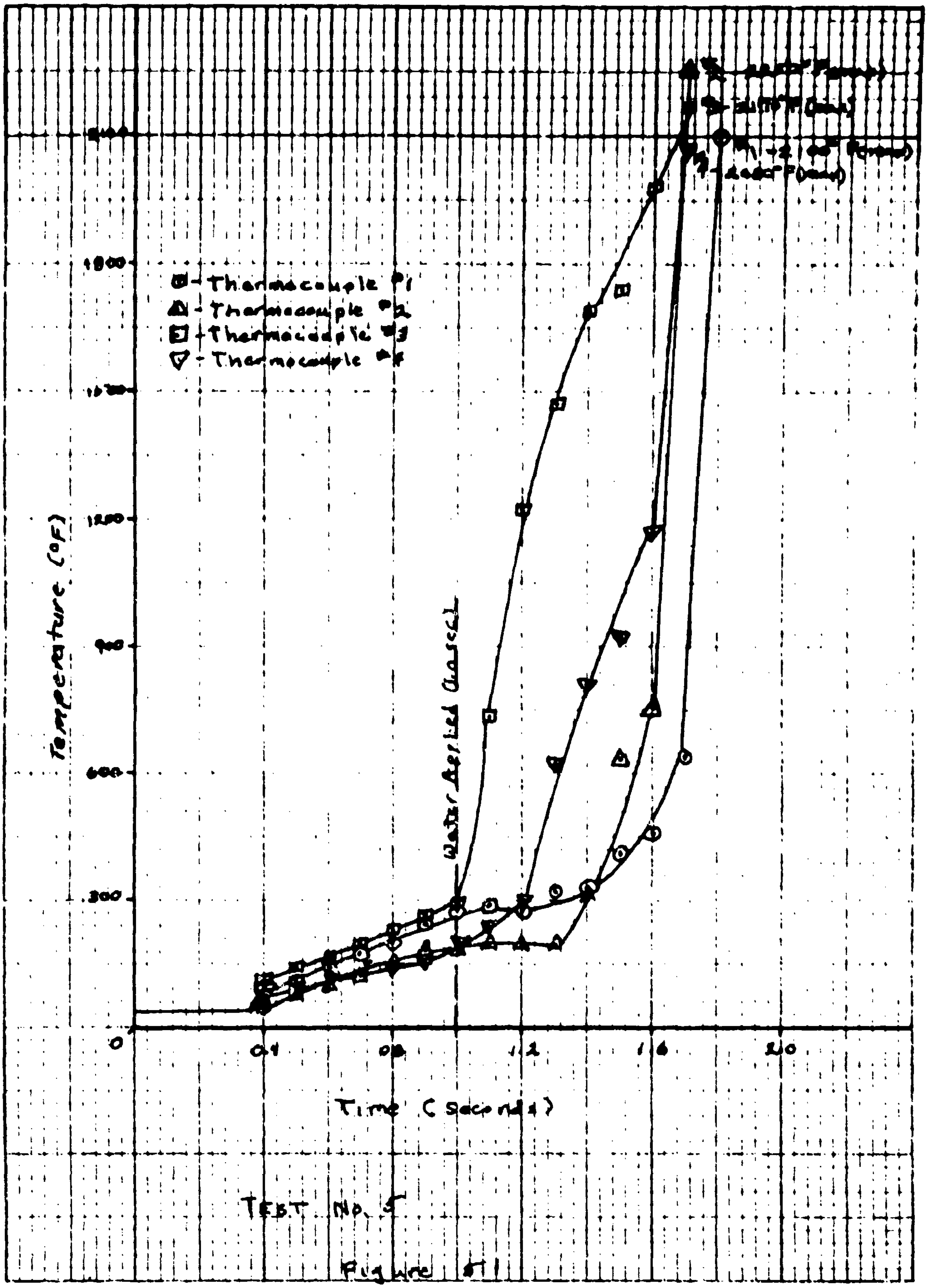
#3 Max Reading 2170°F - 1.7 secs

#4 Max Reading 2080°F - 1.7 sec (See Figure 5.1)

f. Explosion - yes, but did not move shack.

g. Composition - was extinguished approximately 25 lbs was left in mixer. (See photos 5.1 - 5.4).

h. Observations: High velocity spray application did result in extinguishment, but one second delay time allowed temperatures to reach maximum levels. A mild hydrogen explosion did occur when water reached hot composition.


Thermocouple #1
Thermocouple #2
Thermocouple #3
Thermocouple #4
Water Applied (base)
Temperature (°F)
Time (Seconds)
0
300
600
900
1200
1800
0.4
0.8
1.2
1.6
2.0
TEST No. 5
Figure 51

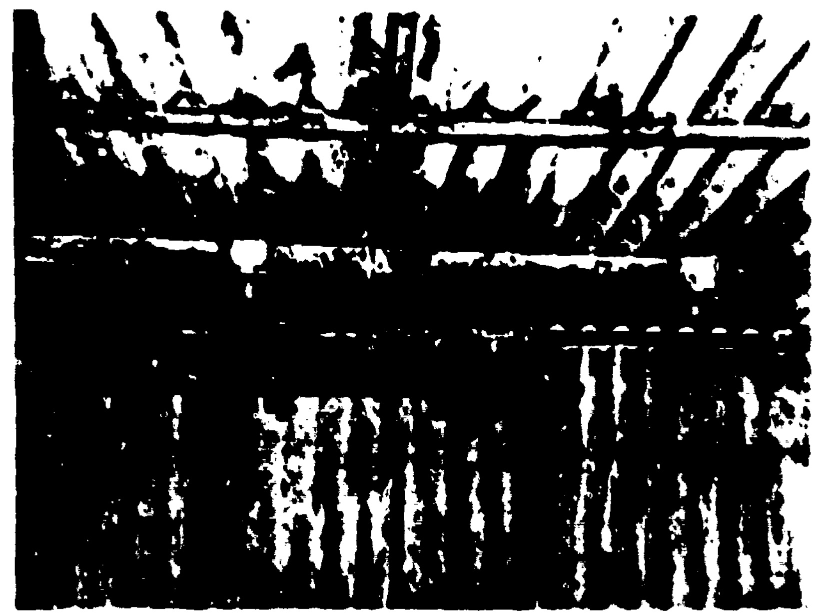


Photo 5.1 - "Sprayco" 6610H Nozzles and brr 's sheet before Test #5

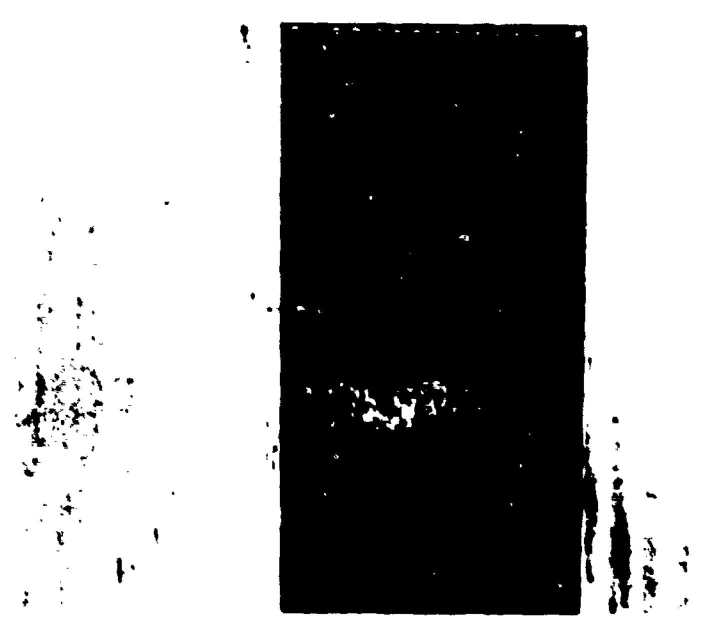


Photo 5.2 - Location of nozzles in respect to mixer

Photo 5.3 - Note: Missing roof sections which blew out in Test #5

Photo 5.4 - Transite from roof was not blown any great distance from shelter. Roof evidently weakened by prior explosions.

6. TEST #6

a. Identical to Test #5 except, two open "Grinnel Quartzoid" sprinkler heads used in lieu of "Sprayco" nozzles. (See photo 6.1, 6.2).

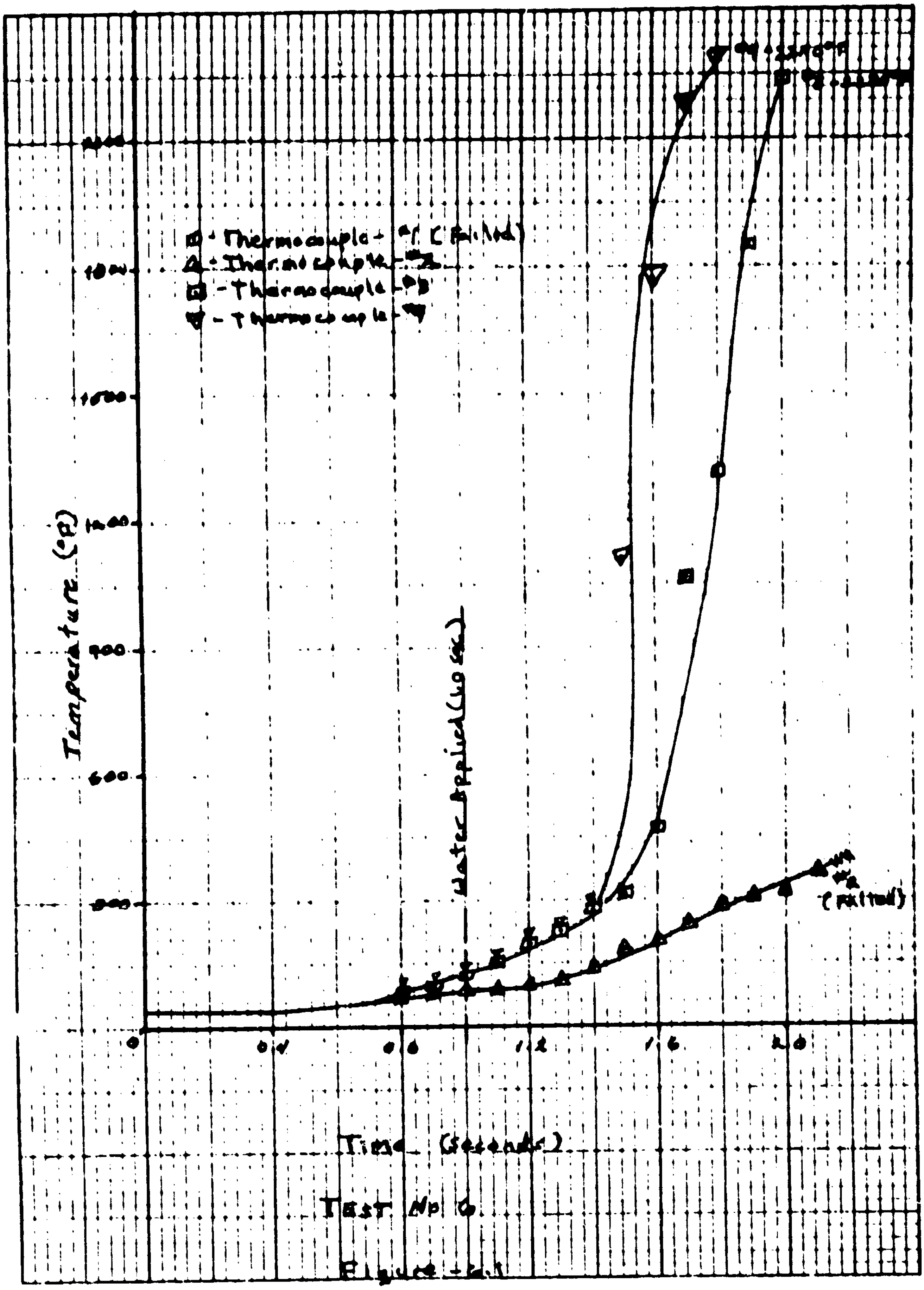
Delay time before water was applied	1 sec
Burning time	9 sec
Pump pressure	120 psi

b. Thermocouples #1 - No readings
#2 - Max reading 370°F - 2.1 secs. Destroyed at 2.2 secs.
#3 - Max reading 2235°F - 2.0 secs.
#4 - Max reading 2290°F - 1.8 secs (See figure 6.1).

c. Explosion - no.

d. Composition was not extinguished.

e. Observations: Water application did prolong flat part of temperature curve, but did not materially effect results.



Test No 6

Figure 2.1

PHOTO LAYOUT - Sheet 17

Photo 6.1 - Location of open "Grinnel" sprinklers before Test #6. Note: Roof had not been patched after Test #5.

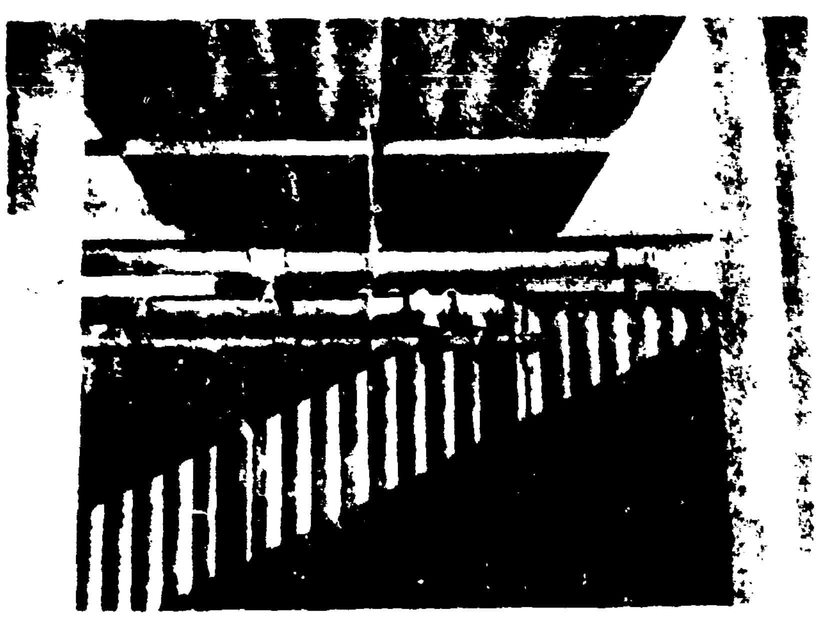


Photo 6.2 - After Test #6 brass sheet and sprinklers undamaged.

7. TEST #7.

a. One batch (125 lbs) Mk 24 APF composition was placed in the mixer. Five "Sprayco 6610H" Automatic Sprinkler Corporation spray nozzles were installed in the test shelter. (See photo 7.1).

b. Water was supplied from a 500 gpm Navy pumper taking suction from a 1200 gallon tank truck as in Tests #5 and #6.

c. The composition was ignited on one side only using a Mk 100 squib.

d. Thermocouples were installed as in Tests #5 and #6.

Delay time before water was applied	1.5 secs
Burning time	8.5 secs
Pump pressure	120 psi

e. Thermocouples #1 - Burnt out (132°F - 1.4 secs).
#2 - 1830 °F - 2.3 secs
#3 - 2025°F - 2.4 secs
#4 - Burnt out (197°F -1.4 secs) (See Figure 7.1).

f. Explosion - yes, but did not move test shelter.

g. Composition was not extinguished. (See photos 7.1 - 7.2)

h. Observations - Angular application of high velocity spray appeared to lift loose composition resulting in more rapid burning.

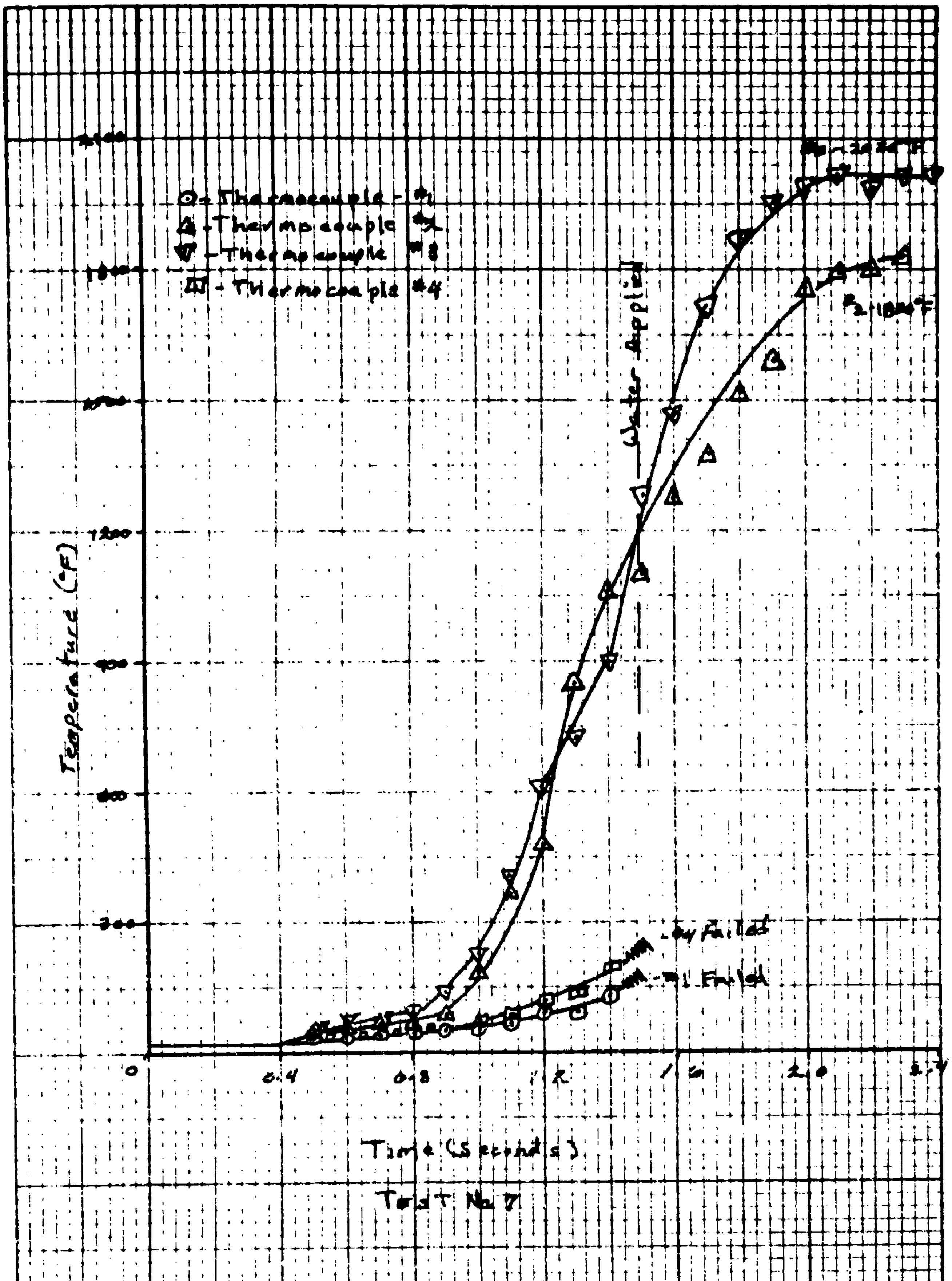

O - Thermocouple #1
Δ - Thermocouple #2
∇ - Thermocouple #3
□ - Thermocouple #4
Water Applied
#4 Failed
#1 Failed
Temperature (°F)
1200
0
0.4
0.8
1.2
1.6
2.0
2.4
Time (Seconds)
Test No 7

Figure T-1

PHOTO LAYOUT - Sheet 18

Photo 7.1 - Five "Sprayco 6610H" nozzles aimed at mixer.

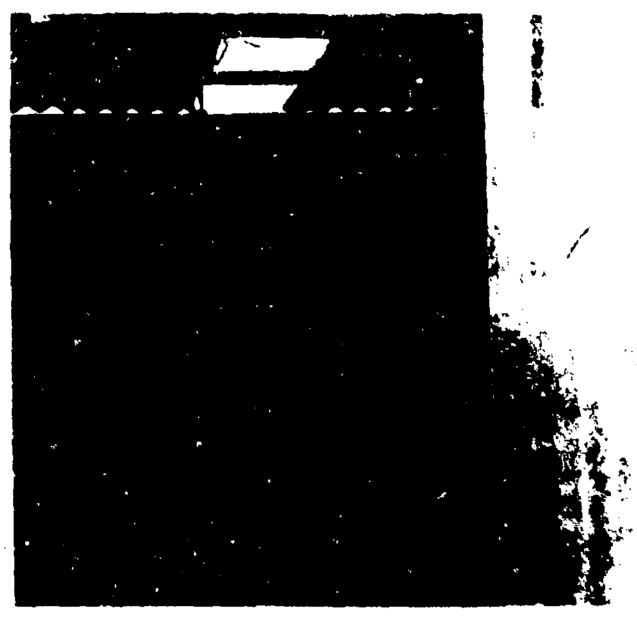


Photo 7.2 - Center section of roof which had survived previous 6 tests blew out.
Note: Copper grounding wire (2/0 AWG) remained in place during Test #7.

8. TEST #8.

a. Identical to Test #7 except that the five spray nozzles were placed directly over the mixer. (See photo 8.1 - 8.2).

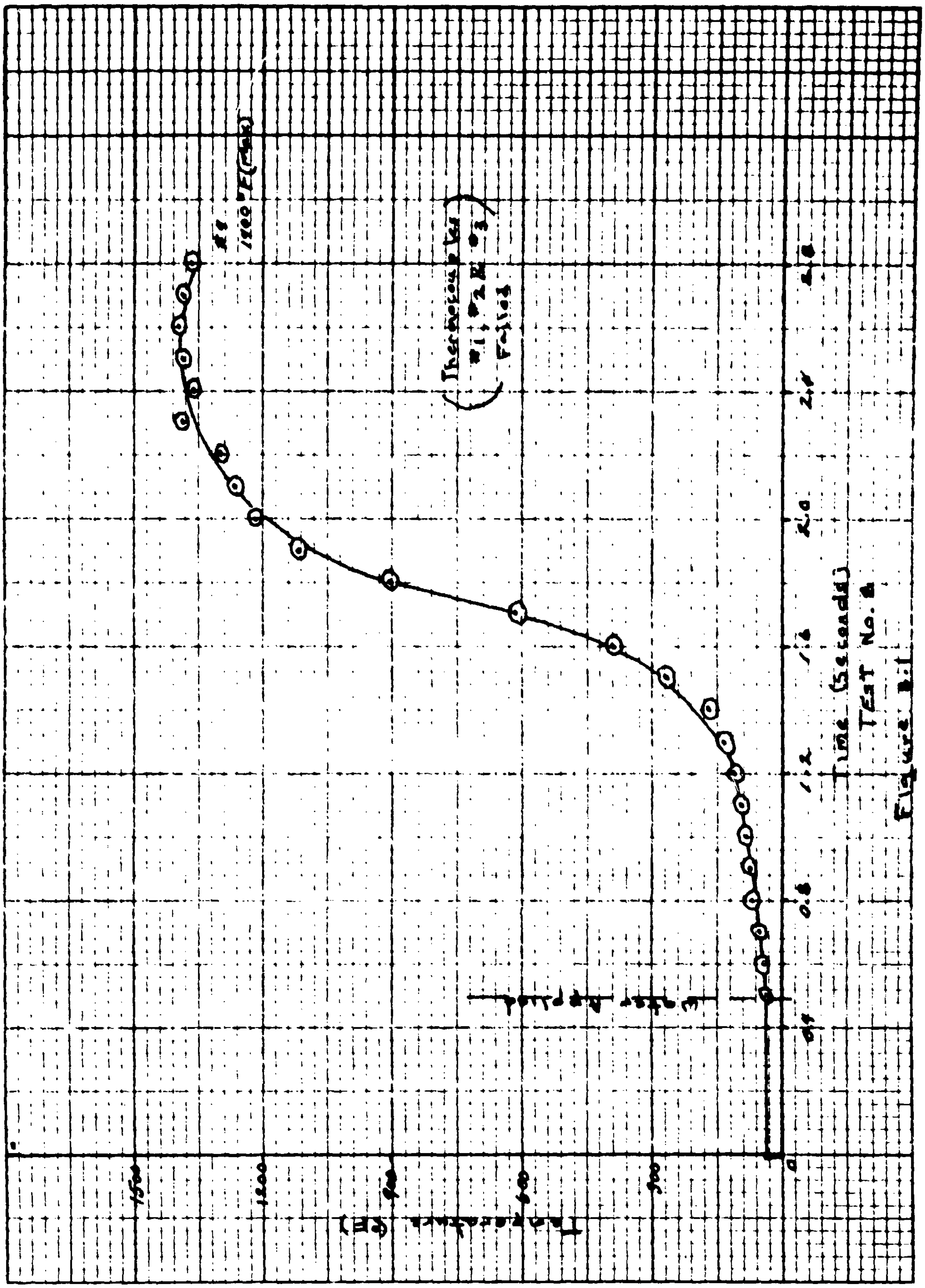
Delay time before water was applied	Approx. 0.5 secs
Burning time	19 secs
Pump pressure	120 psi

b. Thermocouple - #1, #2, and #3 - No reading (See Figure 8.1)
#4 - 1400°F - 2.7 sec

c. Explosion - yes, moved test shelter about 4 feet.

d. Composition was extinguished about 30 lbs left in mixer. (See photos 8.1 - 8.2).

e. Observations: High velocity spray application perpendicular to the burning surface appears to offer best chances of control and eventual extinguishment. Delay times of over 0.5 seconds can result in hydrogen explosions. Laboratory qualitative analysis of material in mixer indicated the presence of magnesium hydroxide ($mg(OH)_2$) as well as elemental magnesium and magnesium oxide (mgo). The reaction of water with hot magnesium will yield $mg(OH)_2$ and hydrogen gas. Previous laboratory tests have indicated granular magnesium will not react appreciably with water at normal temperatures.



Time (Seconds)
TEST No.

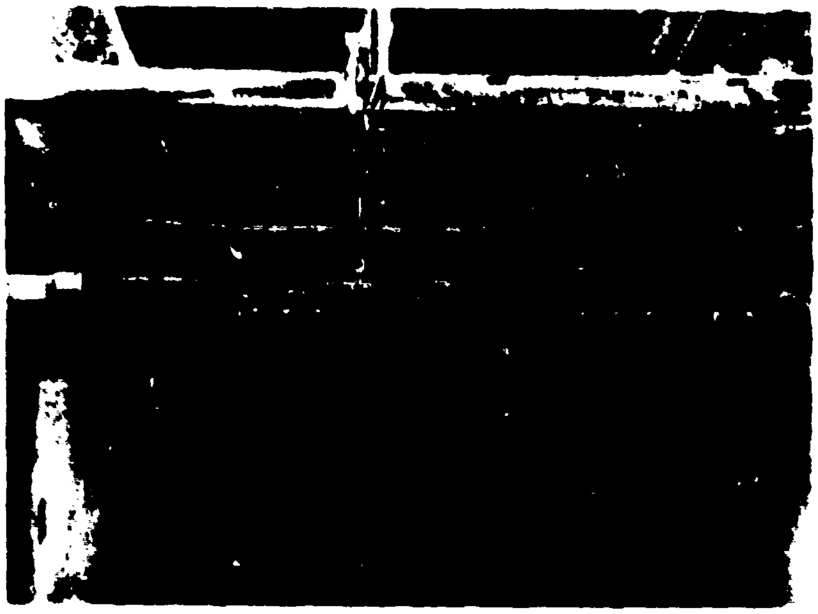


Photo 8.1 - Five "Sprayco 6610H" nozzles directly over mixer for Test #8

Photo 8.2 - Spray discharge pattern for Test #8

PHOTO LAYOUT - Sheet 20

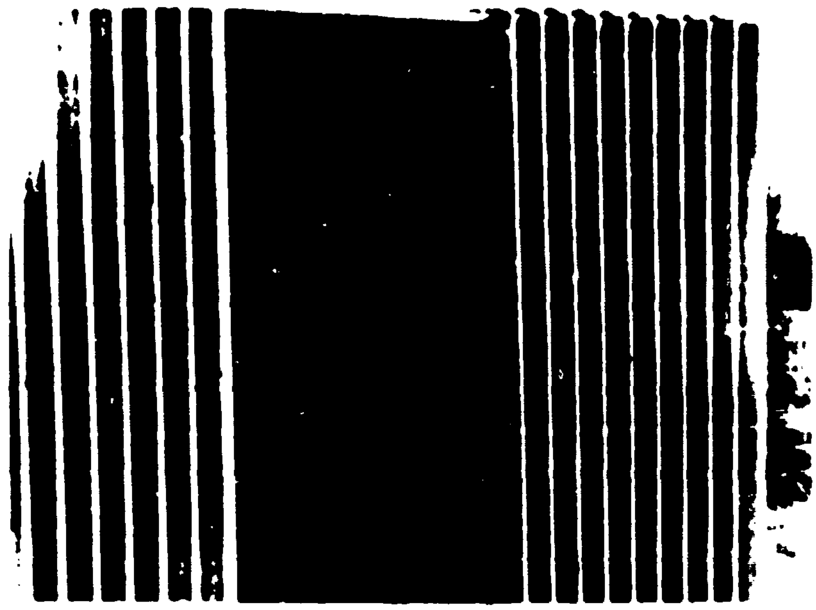


Photo 8.3 - Test shelter moved approximately 4 feet by explosion

9. TEXT #9.

a. Identical to Test #8 except a sixth spray nozzle added in the center. (See photo 9.1 and 9.2).

Delay time before water was applied	0.1 sec
Burning time*	100 secs
Pump pressure	120 psi

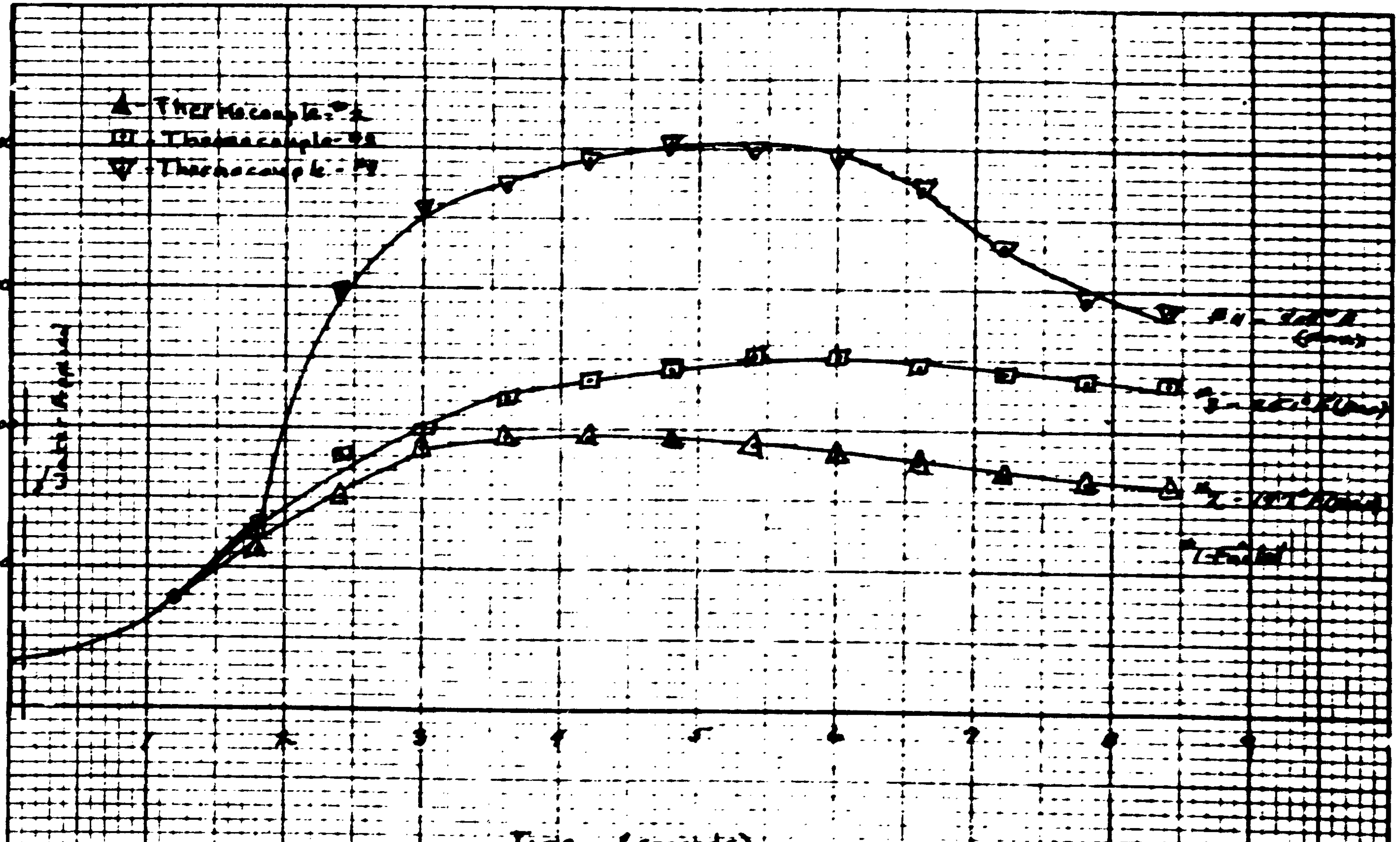
b. Thermocouples #1 - No reading
#2 - 197°F - 12 secs
#3 - 251°F - 18 secs
#4 - 404°F - 20 secs (See Figure 9.1)

c. Explosion - No.

d. Composition was extinguished/about 60 lbs was left in mixer. (See photos 9.1 - 9.4).

e. Observations: Excellent temperature control. Personnel in a cell could have survived the fire.

* Pump operator momentarily shut-off pump before fire was totally extinguished at approximately 10 seconds after ignition. Fire ball redeveloped, but was finally extinguished.



TEST No. 9

Figure 9.1

Photo 9.1 - Six "Sprayco 6610H" nozzles directly over mixer for Test #9

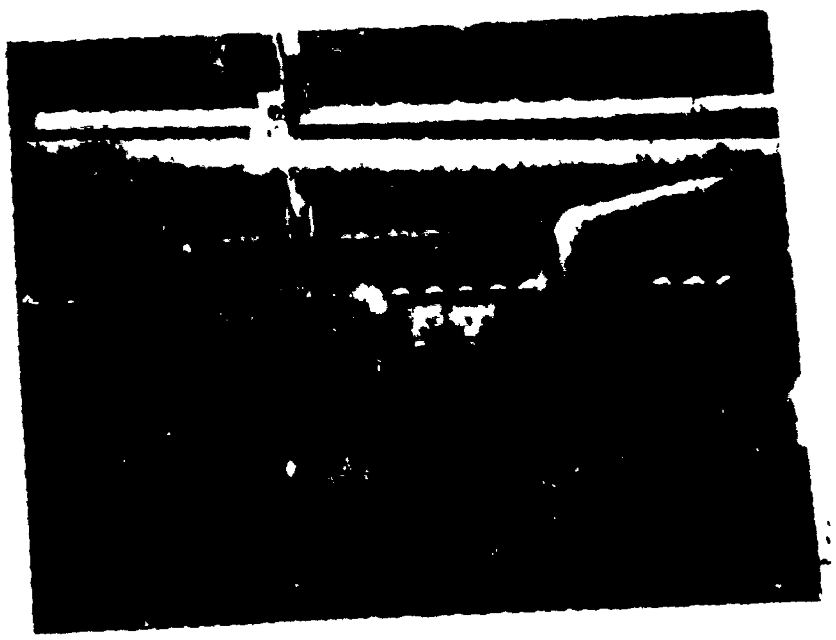


Photo 9.2 - Note: Copper grounding wire (2/0 AWG) still in place after Test #9

PHOTO LAYOUT - Sheet 22

Photo 9.3 - Coveralls placed on outside of shelter to dry were not damaged during Test #9

10. TEST #10.

a. Identical to Test #9

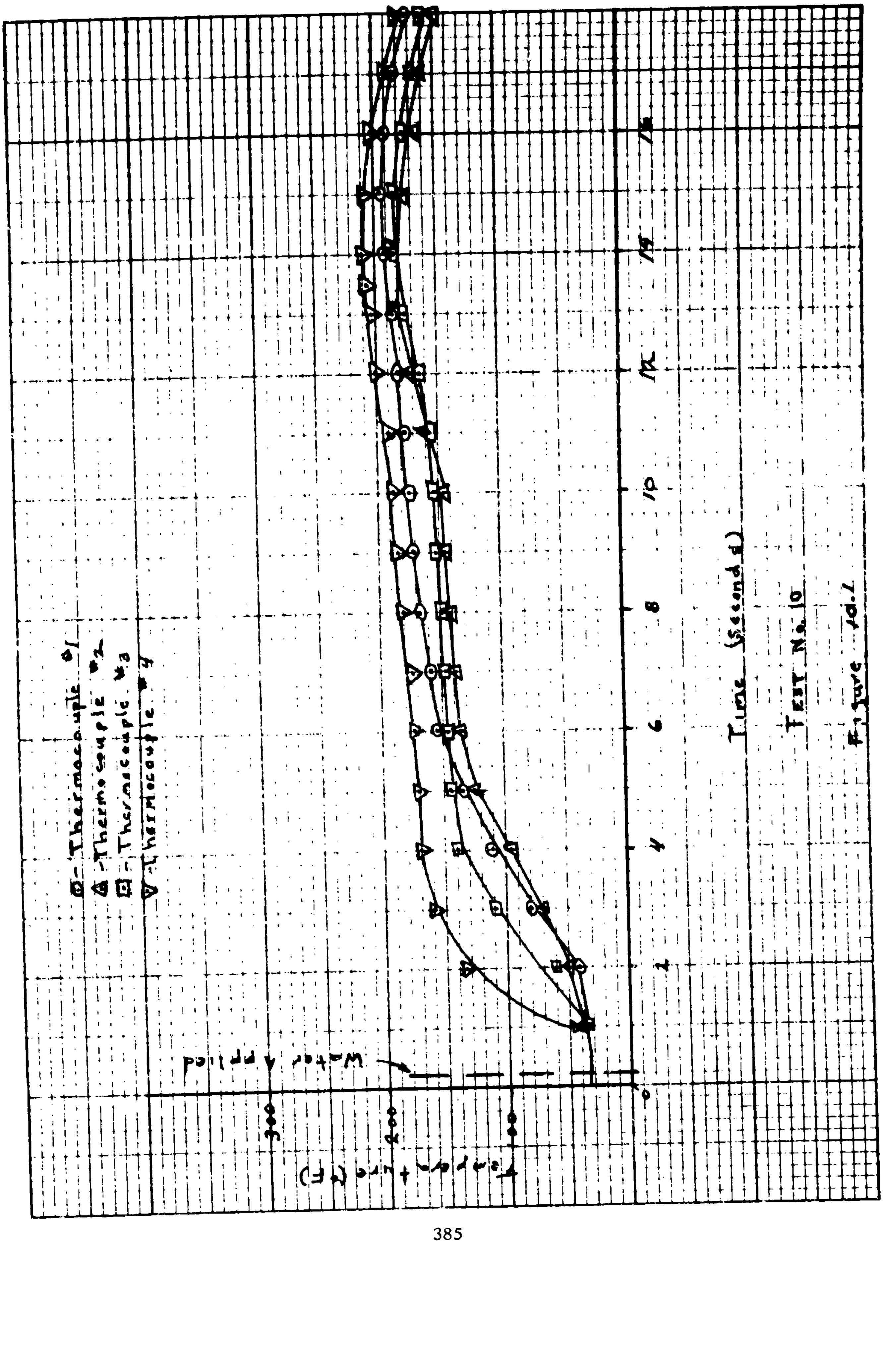
Delay time before water was applied	0.2 secs
Burning time	70 secs
Pump pressure	120 psi

b. Thermocouple #1 - 197°F - 14 secs
#2 - 183°F - 14 secs
#3 - 185°F - 14 secs
#4 - 208°F - 14 secs (See Figure 10.1)

c. Explosion - No.

d. Composition was extinguished/about 30 lbs was left in mixer.

e. Observations: High volume, high velocity spray application within 0.2 seconds effectively controls temperatures until the composition fire can be extinguished.



Thermocouple #1
Thermocouple #2
Thermocouple #3
Thermocouple #4
Water Applied
Temperature (°F)
100
200
300
0
2
4
6
8
10
12
14
16
Time (Seconds)
Test No. 10
Figure 10.1

11. TEST #11.

a. Approximately 60 lbs of granular magnesium was placed in the mixer. Six "Sprayco 6610H" spray nozzles were placed over the mixer, as in tests #9 and #10.

b. Water supply, thermocouples, etc. were identical to those in tests #8, #9 and #10.

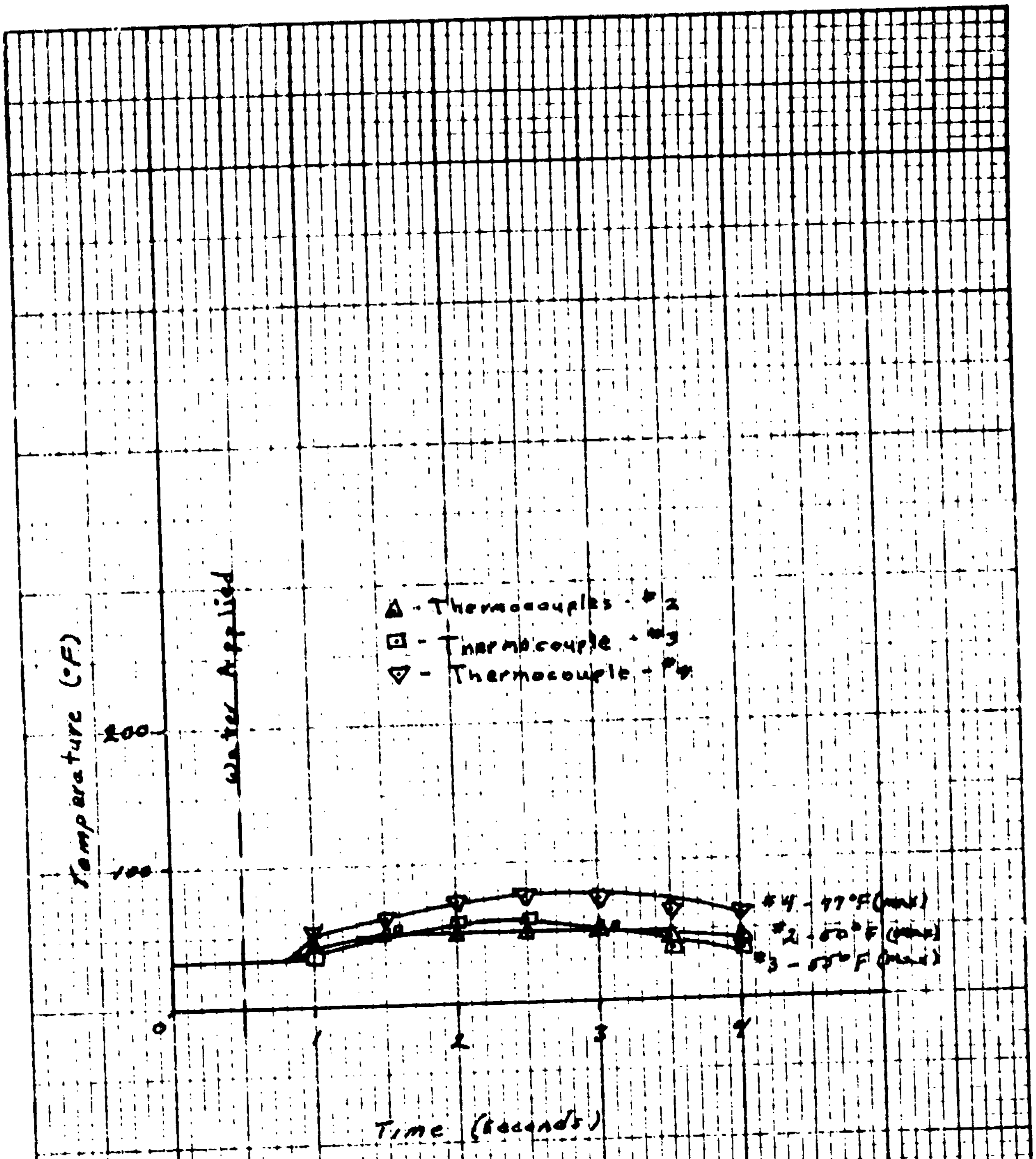
Delay before water was applied	0.5 secs
Burning time	4 secs
Pump pressure	120 psi

c. Thermocouples #1 - No reading
#2 - 50°F - 1.5 secs
#3 - 55°F - 2.0 secs
#4 - 77°F - 2.4 secs (See Figure 11.1).

d. Explosion - No.

e. Magnesium was extinguished.

f. Observations: Fires involving the bare, granular magnesium develop slowly and can be readily extinguished in the incipient stage with high volume water applications.



TEST No. 11

Figure 11-1

12. TEST #12.

a. A total of 54 bare Mk 24 APF candles were placed in a plated brass box the approximate size of candle cart used at NAD Crane. (See photo 12.1).

b. Five "Sprayco 6610H" nozzles were placed over the cart as in Test #8.

c. Water was supplied as in Test #8, #9 and #10.

d. Two flares were ignited.

Delay time before water was applied	15 secs
Burning time	7 min.
Pump pressure	120 psi

e. Thermocouples #1 - 2320°F, 130 secs - destroyed.
#2 - Wire burnt
#3 - Transite wall spalled away
#4 - 1896°F - 115 secs - destroyed

f. Explosion - No.

g. Candles were not extinguished. (See photos 12.1 - 2.6)

h. Observations: Fire was purposely allowed to spread to most of the candles before water application. Spray pattern was not adequate to penetrate fire balls.

* Water from first 600 gallon compartment of 1200 gallon tanker was exhausted - control of the fire was lost during switching operations - sprinkler brackets burnt-out and allowed piping to fall. Test shelter was badly damaged.

Photo 12.1 - Spray nozzle and candle arrangement before Test #12

Photo 12.2 - Fire at time of water application

PHOTO LAYOUT - Sheet 24

Photo 12.3 - Fire after control was lost

Photo 12.4 - High point of fire. Note: Heavy smoke and intense light totally block vision of actual burning area.

PHOTO LAYOUT - Sheet 25

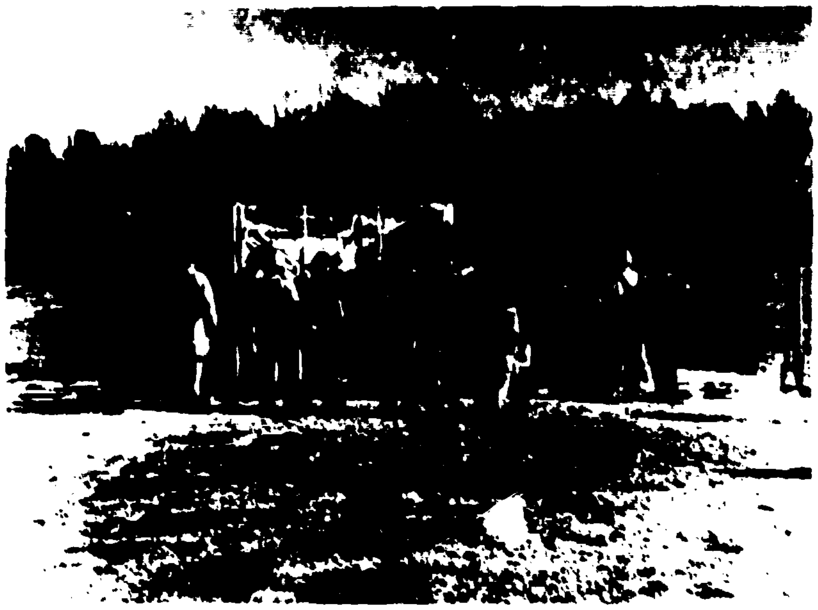


Photo 12.5 - Note: Roof of test shelter collapsed during fire.

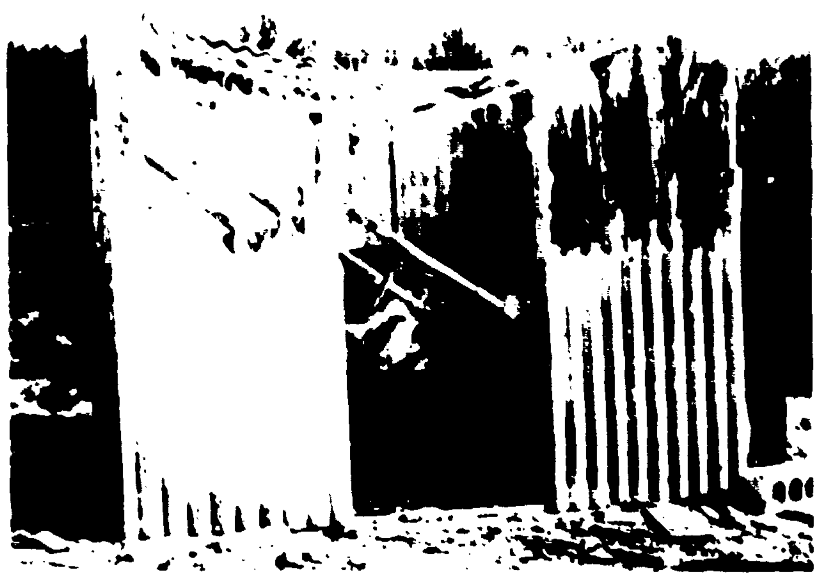


Photo 12.6 - Note: During the first part of fire, the water pipe supports burnt out allowing pipe to droop.

13. TEST #13

a. A total of 54 bare Mk 24 APF candles were placed in the brass box as in test #12. (See photo 13.1).

b. Six "Sprayco 6610H" spray nozzles were positioned over the cart as in tests #9, 10, and 11.

c. Two candles were ignited as in test 12.

Delay time before water was applied	1.5 sec.
Burning time	5 min.
Pump pressure *	120 psi

d. Thermocouples #1 - 60°F Max.
#2 - 60°F Max.
#3 - 60°F Max.
#4 - 60°F Max.

e. Explosion - No.

f. One candle burnt out/all others were extinguished or prevented from igniting. (See photo 13.2).

g. Observations: With even a moderate delay after ignition, the burning candles can be extinguished or controlled to prevent ignition of adjacent candles.

* Tank truck was modified to allow use of full 1200 gallons with one suction hose.

PHOTO LAYOUT - Sheet 26

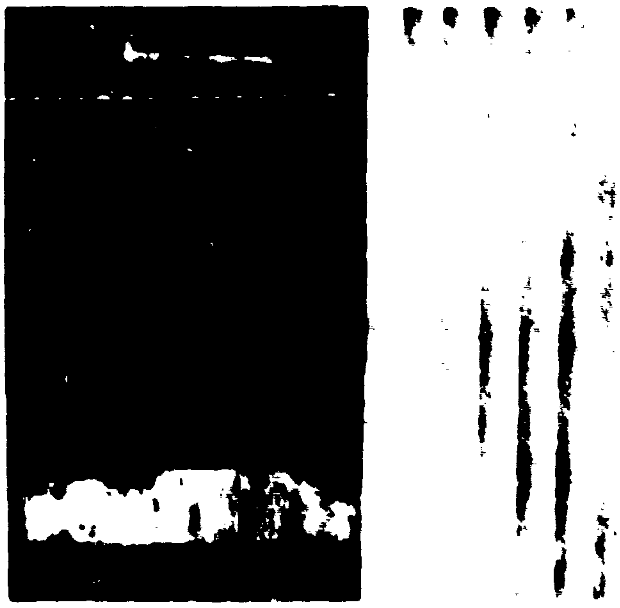


Photo 13.1 · Spray nozzle and candle arrangement before Test #13

Photo 13.2 - Note: Center candle in row 3 ignited but was extinguished. Center candle in row 8 ignited and was consumed, but adjacent candles did not burn.

14. TEST #14

a. Identical to Test #13 except that a delay of 5 seconds was used. (See photo 14.1).

Delay time before water was applied	5 secs
Burning time	6 min - 40 sec
Pump pressure	120 psi

b. Thermocouples: #1 - 1222°F - Max
#2 - 220°F - Max
#3 - 1162°F - Max
#4 - 620°F - Max

c. Explosion - No.

d. All but nine flares burnt out. (See photos 14.1 - 14.3).

e. Observations: High velocity spray applications can control burning rate and dramatically reduce maximum temperatures, but do not effectively extinguish fires involving large numbers of candles closely grouped. Straight stream water applications that have proven themselves effective on completed flares would probably be the best choice for this type of fire.

PHOTO LAYOUT - Sheet 27

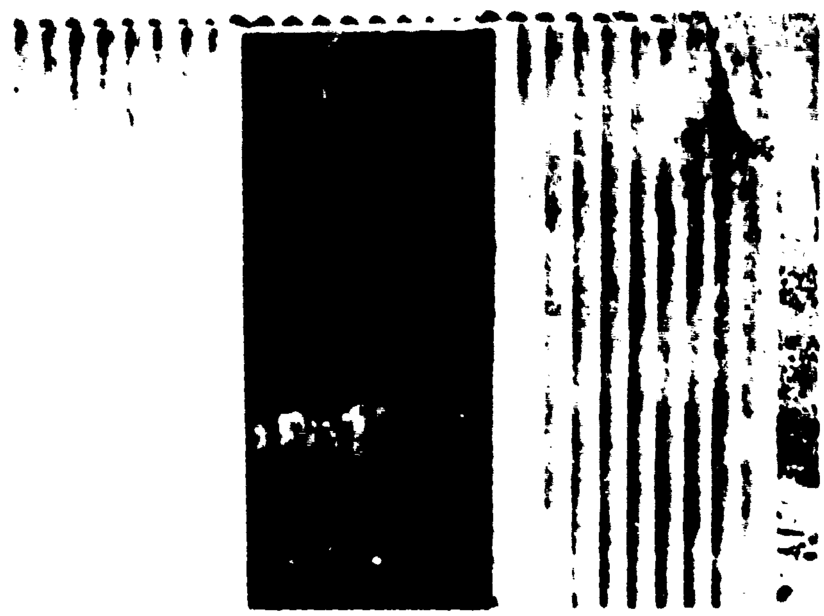


Photo 14.1 - Spray nozzle and candle arrangement before Test #14

Photo 14.2 - Note: Only candles located directly under a spray nozzle were not consumed.

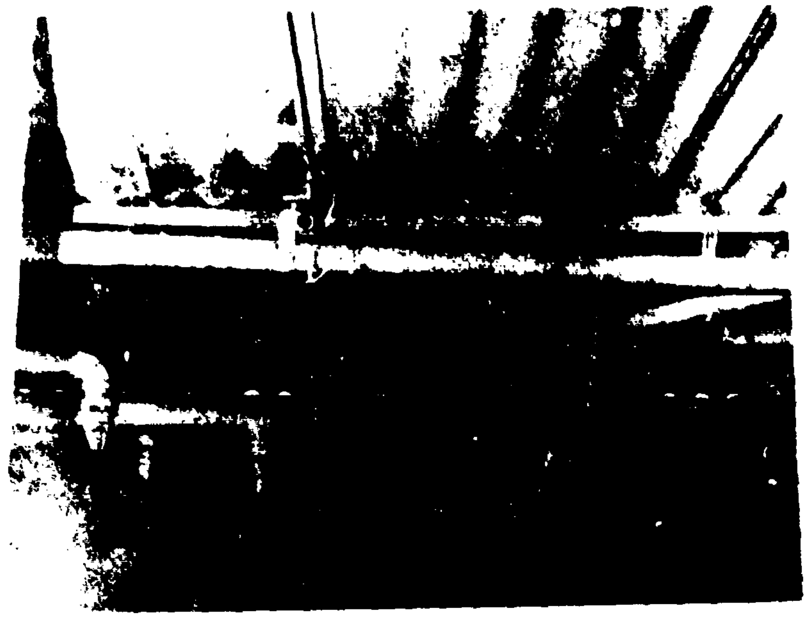


Photo 14.3 - Copper grounding wire (2/0 AWG) was not damaged by fire

SUMMARY:

1. Test #1 - 4 and #6 - indicated water application from ordinary sprinkler heads would not control the fireball development of burning loose composition even when applied within 50 milliseconds of ignition.

2. Test #7 - indicated water spray application from a side angle tends to lift the composition resulting in more violent burning and loss of control.

3. Tests #5, 8 - 11 -indicated direct overhead application of water in large quantities within 0.5 seconds of ignition can effectively control fires in loose Mk 24 APF mixes and granular magnesium.

4. Tests #12 and 14 - indicated delay times before water application on bare candle fires must be held to less than 5 seconds and water must reach all candle faces.

5. Test #13, - indicated that large volumes of water applied to vertically stacked candles can control fires and prevent fire spread from candle to candle.

CONCLUSIONS:

1. Mk 24 APF composition fires in mixers can be controlled and/or extinguished with high volumes of water applied from a high velocity spray nozzle within 0.5 seconds of ignition.

2. Inadequate water volume, poor water application patterns or application of water after 0.5 seconds after ignition, can result in hydrogen explosions. However, the explosion force is not sufficient to cause material structural damage.

3. Failure to extinguish or gain control of Mk 24 APF mixer fires within the first 0.5 seconds after ignition allows temperatures to exceed 2200° within the cell even at the floor level.

4. Fires involving as many as 54 bare Mk 24 APF candles can be controlled with high volume water application on candle faces within 1.5 seconds after ignition.

5. Further detailed and closely controlled testing is required to ascertain the most effective fire extinguishment and control systems for pyrotechnic production storage facilities.

LIQUID EXPLOSIVE DETONATION TRAPS - A SURVEY

by

M. F. Zimmer, C. Dale, L. Lipton
Naval Ordnance Station, Indian Head, Maryland

A fundamental problem in the manufacture and use of many combustible or explosive liquids is the danger of an accidentally-initiated detonation in the liquid which may propagate along the various transfer lines in a facility.

On December 14, 1967, such an accident occurred at the Biazzi nitroglycerine plant at NAVORDSTA. Some 4,000 pounds of NG exploded, and although there were no injuries to personnel, the facility was extensively damaged. Many other similar incidents have occurred at various locations around the world. Thus, it appears that additional safety developments are needed.

The risk of detonation is not limited to "explosives"; most monopropellants (such as Otto fuel) will sustain a detonation under certain conditions. Therefore, the problem is one of widespread importance.

Precautions are generally taken to minimize the risk of accidental initiation; nevertheless, incidents continue to occur, indicating the need for an additional approach.

In production plants, since the explosive liquid is generally divided between several storage or handling areas which are connected by transfer lines, it seems logical to try to minimize the loss in an accidental explosion by isolating it; that is, by preventing the explosion from propagating through the transfer line. This is the function of a detonation trap (quencher, arrestor).

The trap is inserted in the transfer line, and while it ideally does not impede the normal flow of liquid, any detonation is not allowed through. This paper presents a survey of some actual, possible, and speculative designs.

There are two approaches toward the trap design: if we can find a theoretical condition which prevents propagation, we can design a trap utilizing this condition. This type of trap is automatic, or intrinsic, i.e. because of its inherent design, a detonation cannot pass through it. The other approach is an externally activated mechanical trap which physically affects the liquid before the detonation wave arrives.

The ideas which are interesting for the design of detonation traps are the experimentally observed methods of rendering a detonation impossible, and theoretical models which involve certain removable parameters. If any of these parameters are necessary for a detonation, judicious selection and control of appropriate trap characteristics should be effective in blocking the propagation of the explosion.

There are consequently a number of possible types of trap; the following is a summary list of types with varying degrees of probabilities of success and/or favorable test results. Explanations of the mechanism of each trap follow.

1. Critical diameter
2. Precompression
3. "Dead-wall"
4. Diameter transition and "Aquarium"
5. Line-severing (the "loop" type is an example)
6. Externally-activated type (e.g., extinguisher injection, E-A line severing, etc.)

1. Critical Diameter Trap

A characteristic of explosives is the critical diameter, below which a detonation fails to propagate. In practical cases, it is recognized that the container and wall thickness as well affects the value of the critical diameter (Table 1).

Two types of detonation trap based on the critical diameter of the liquid are recognized as feasible: 1) The use of multiple branches made up of pipes whose diameter is below the critical value, (Figure 1) and 2) A plastic plug with parallel holes drilled through its length. Each hole is below the critical diameter. (Figure 2) The plug type of trap has been successfully used. In contrast, a bundle of small diameter steel tubes inside of a larger steel pipe did not quench a detonation even though the small tubes were below the critical diameter for the liquid.

Frequently it is possible to design transfer lines such that no detonation trap is needed by either staying under the critical diameter, if practical for the liquid in question,or else raising the critical diameter of the liquid

FIGURE 1. MULTI-BRANCH DETONATION TRAP

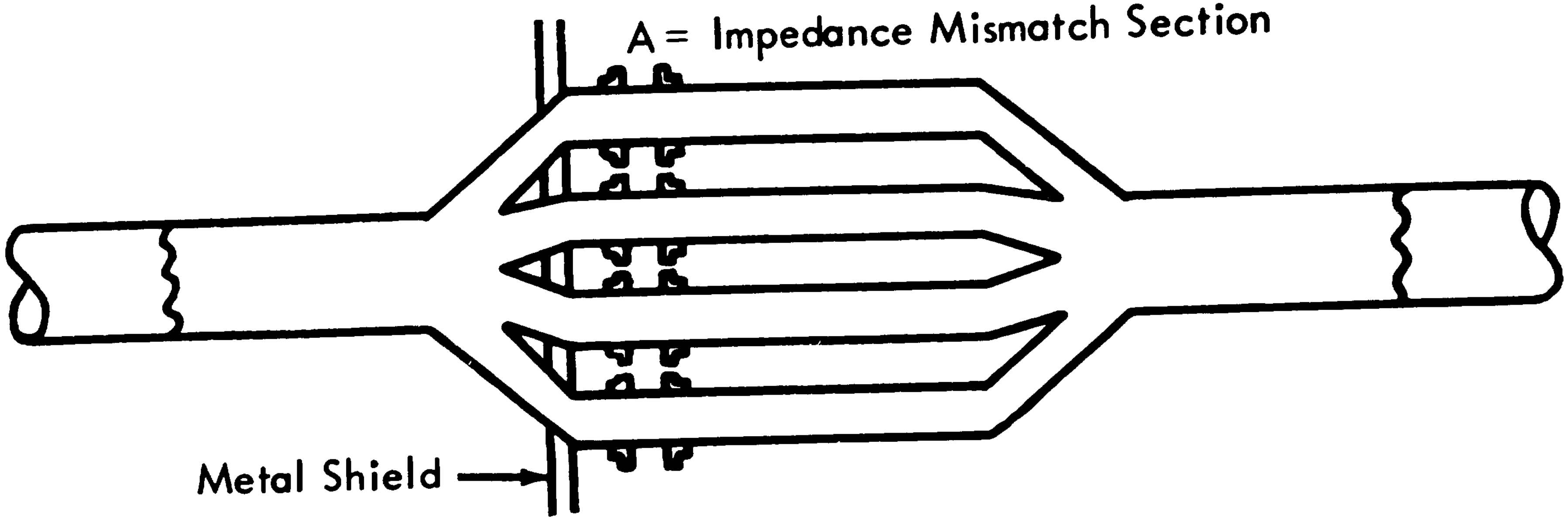
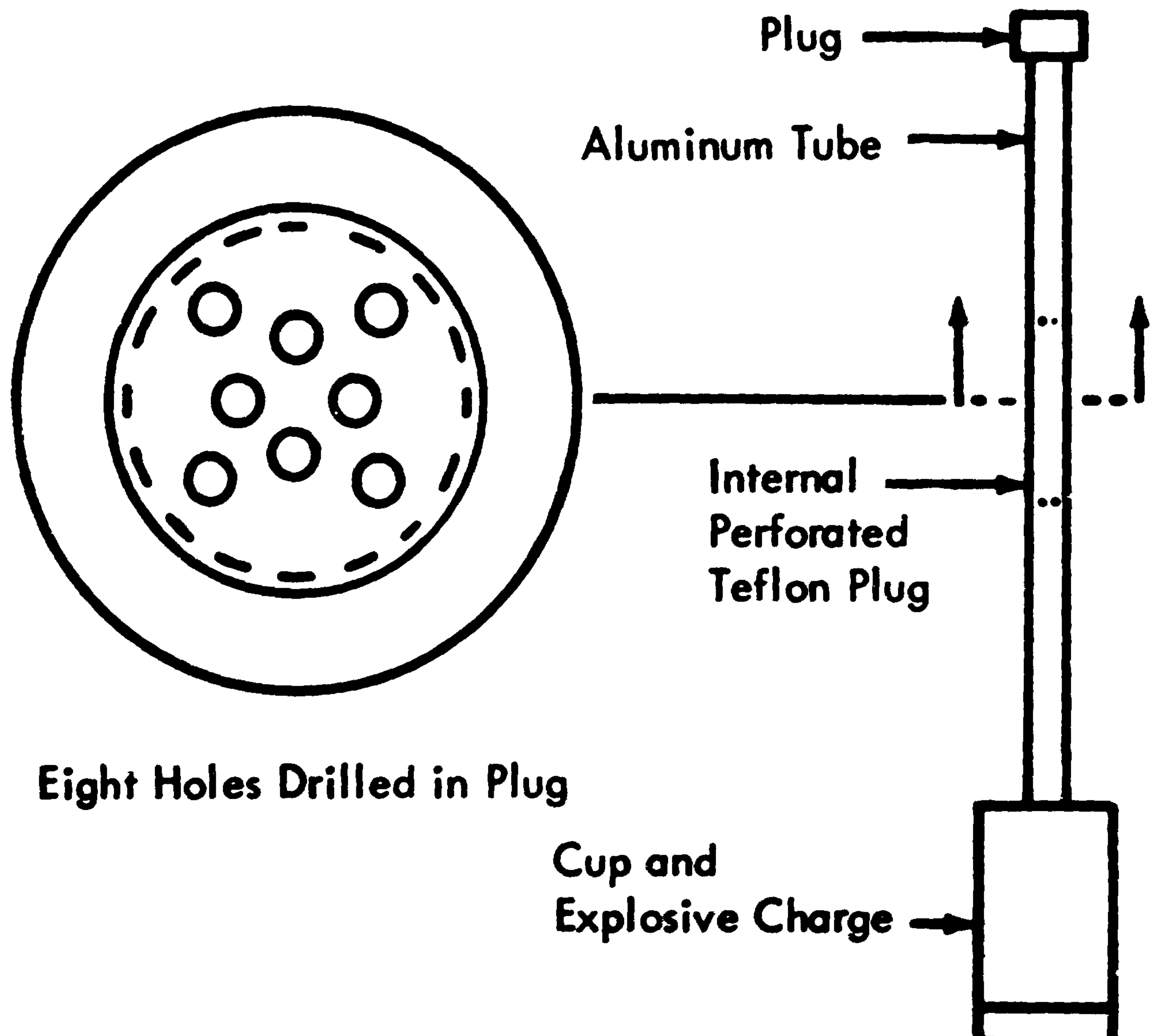


FIGURE 2. PLUG DETONATION TRAP



above the diameter of practical lines by the addition of diluents. For instance a mixture of 80% hydrocarbon carrier with 20% (by weight) of 90-10 NG/TA was found not to detonate in a 0.75 inch i.d. pipe (4).

Many liquid explosives exhibit, in addition to the thermodynamically expected detonation velocity, (high velocity, HVD) an anomalously low detonation velocity(LVD). Wedge experiments conducted by Bureau of Mines, indicate that critical diameter for LVD of the tested liquids is below that for HVD(5). Because LVD is more likely in an accidental explosion, critical diameter traps probably would have only a limited usefulness in actual application.

2. Precompression Trap

Drimmer et. al. at NOL have investigated the failure of detonation under precompression of the explosive. A trap which has been designed using this principle (6) is illustrated in Figure 3. In this trap, the channel through which the liquid explosive flows is of rectangular cross section (width: height = 8 or 10:1). A detonation entering either section X or Y induces a shock wave in the inert separation medium. Geometry and materials are selected to allow the inert shock to compress part of the unreacted fluid in Z, to the correct pressure, (about 50% of initiation pressure) just before the original detonation can reach this area. The result should be a quenching of the detonation. It is obvious that its configuration must be carefully determined

so that precompression occurs at precisely the right time and is of the correct amplitude.

3. "Dead-Wall" Trap

According to Watson [7], (cavitation model) if the liquid explosive container walls have a higher sonic velocity than the liquid itself, a precursor wave in the wall will travel ahead of the reacting shock, and compress the unreacted fluid. An expansion of the container wall (caused by the reaction zone itself) than reduces the pressure in the liquid. The rapid depressurization produces cavitation (gas bubbles), which become centers of initiaiton when the shock in the fluid reaches them. Bureau of Mines experimental evidence includes the observation of instability of LVD in lead tube containers, whereas LVD was stable in steel tubes; the difference in results is assumed to result from the low sound velocity in lead. Other investigation [7] however, has produced stable LVD in paper and cork tubes.

Another theory [9] involving wall propagation assumes that the supersonic wall precursor produces a cone-shaped bow wave in the fluid forming a disc-shaped Mach stem of high enough pressure to initiate the explosive. It should be noted the Mach stem phenomenon can occur under two somewhat different circumstances. The case mentioned here is the interaction of intersecting shock fronts. When the angle of intersection (vertex) is below a critical value, the intersection region ceases to be a point or line, and becomes a lateral plane,

truncating the point of the intersection. In this case of a rear-pointing conical "bow wave", truncation **produced** by the Mach stem is disc-shaped.

Eliminating the wall precurosr would obviously eliminate the Mach disc. In the case of the cavitation model, absence of the wall precursor would reduce the decompression of the fluid during wall expansion, reducing the cavitation effects.

A construction utilizing alternate segments of materials with widely different shock impedances would reduce the shock transmission drastically. Materials with low shock impedances might also be of use here. This is the so-called "dead-wall" trap. (Figure 4)

Additionally, the Mach disc model leads to the conclusion that charge geometry (for instance, cross-section configuration) affects the stability of the detonation. For example, rectangular charge configurations of liquid explosives have been found to be less sensitive to initiation than cylindrical tubes.[9] Therefore, charge geometry may be useful for quenching a detonation; on the other hand LVD in nitroglycerin has been obtained readily in rectangular tubes too.[10]

4 Diameter Transition and Aquarium Trap

Since both traps are based on eliminating wall reflections in the detonation process, they shall be discussed together.

Wall reflections are necessary for an LVD model which again involves the Mach stem. Another case of this phonomenon

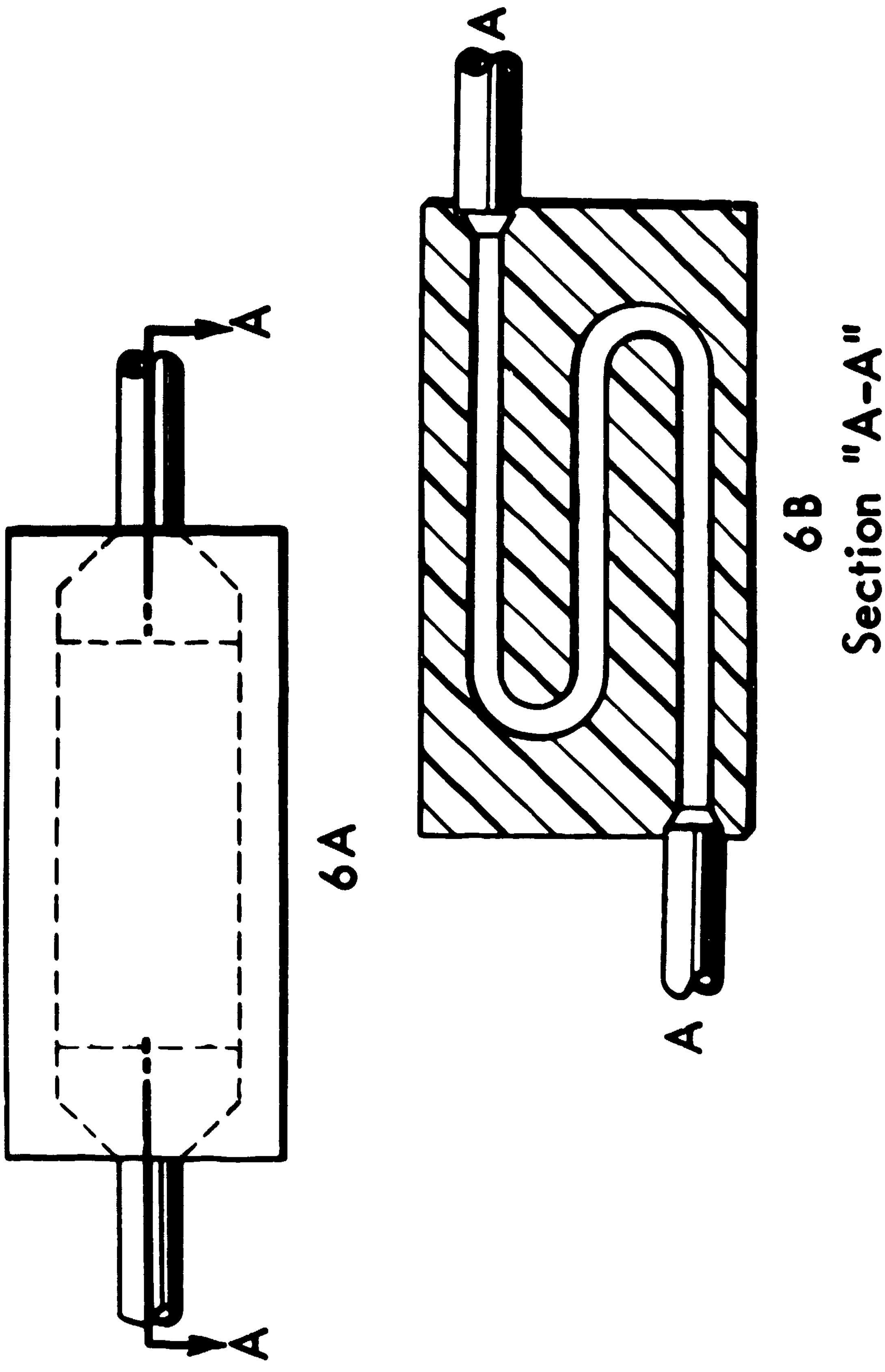
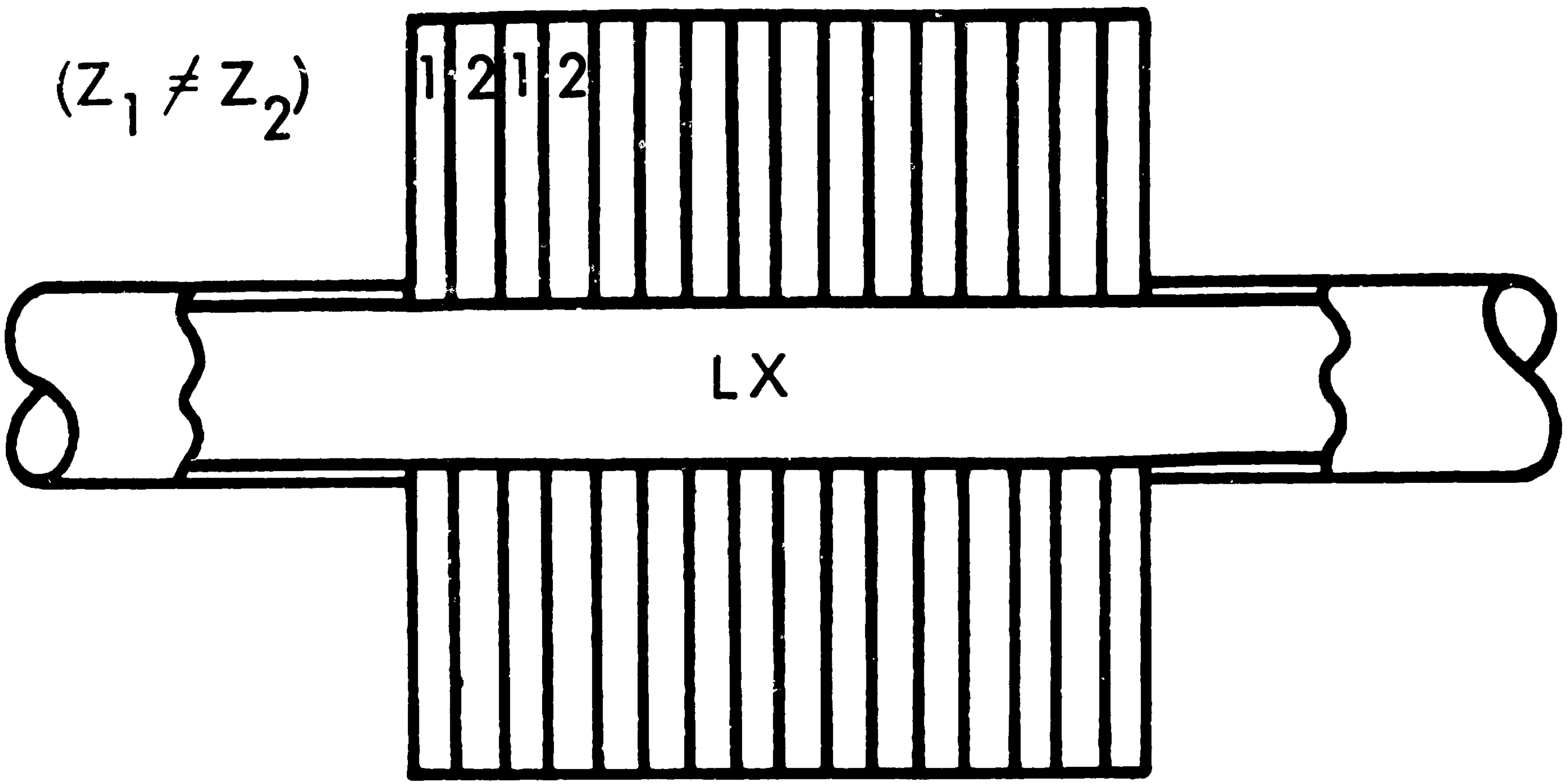

A
A
6A
A
A
6B
Section "A-A"

FIGURE 4. "DEAD-WALL" TRAP



is the interaction of a shock front with a reflective boundary. When the incidence angle to the boundary (measured from the perpendicular) is below a critical value, the intersection point of incident and reflected waves leaves the boundary surface, becoming separated from it by a third wave front, the Mach stem. The formation of Mach waves under certain conditions are assumed to be a sufficient requirement for initiation and propagation of LVD.

A mechanism for HVD in certain liquid explosives has been proposed by Dremin[11] which is based on the assumption that the detonation wave, rather than being smooth, contains inhomogeneities caused by variations in the ignition delay time of the explosive. With NM-acetone mixtures, these inhomogeneities propagate across the shock front, reflect from the walls and finally collide with each other. The collision sites are centers of initiation of that layer of explosive. Based on the hypothesis that wall-reflections affect initiaition and propagation of detonation, elimination of wall reflection should minimize the possibility of initiation and quench detonation. The influence of wall reflection on the induction time of LVD in nitroglycerin has been demonstrated[10].

Elimination of wall reflections is difficult, but nevertheless seems feasible. If the liquid explosive transfer line enters a larger diameter line abruptly, the walls are effectively "removed" (temporarily, at least) for a detonation

wave entering the larger tube. (Figure 5) Under the correct circumstances, this "diameter-transition" trap can quench the detonation and this has been achieved in laboratory tests. It appears, however, that there are critical parameters involved here which may make a trap of practical size unfeasible.

Another method of removing the wall reflections is to surround the charge with an inert medium of similar shock impedance characteristics. (Figure 6) If the two substances can be effectively separated during normal operation by a material which would efficiently couple shocks in the explosive out into the inert acceptor medium, the Mach stem, or any other phenomenon dependent upon internal reflection of disturbances, could not exist in the charge. Hopefully, the result would be quenching of the detonation. This so-called "aquarium" trap has been tested in prototype form and appears to drastically reduce the propagation velocity of a detonation. In these tests,[11] a pure NG charge ($d = 27$ mm) was contained in a thin Mylar tube, which in turn was surrounded by a dense zinc chloride aqueous solution of $\rho = 1.6$ or 1.74 g/cm^3. In one test, the charge was not initiated by the squib used; in a second, a long initiation delay (75 µsec) and a low reaction velocity (620 m/sec) resulted. Conclusive results, of course, await more extensive testing.

FIGURE 5. DIAMETER TRANSITION TRAP

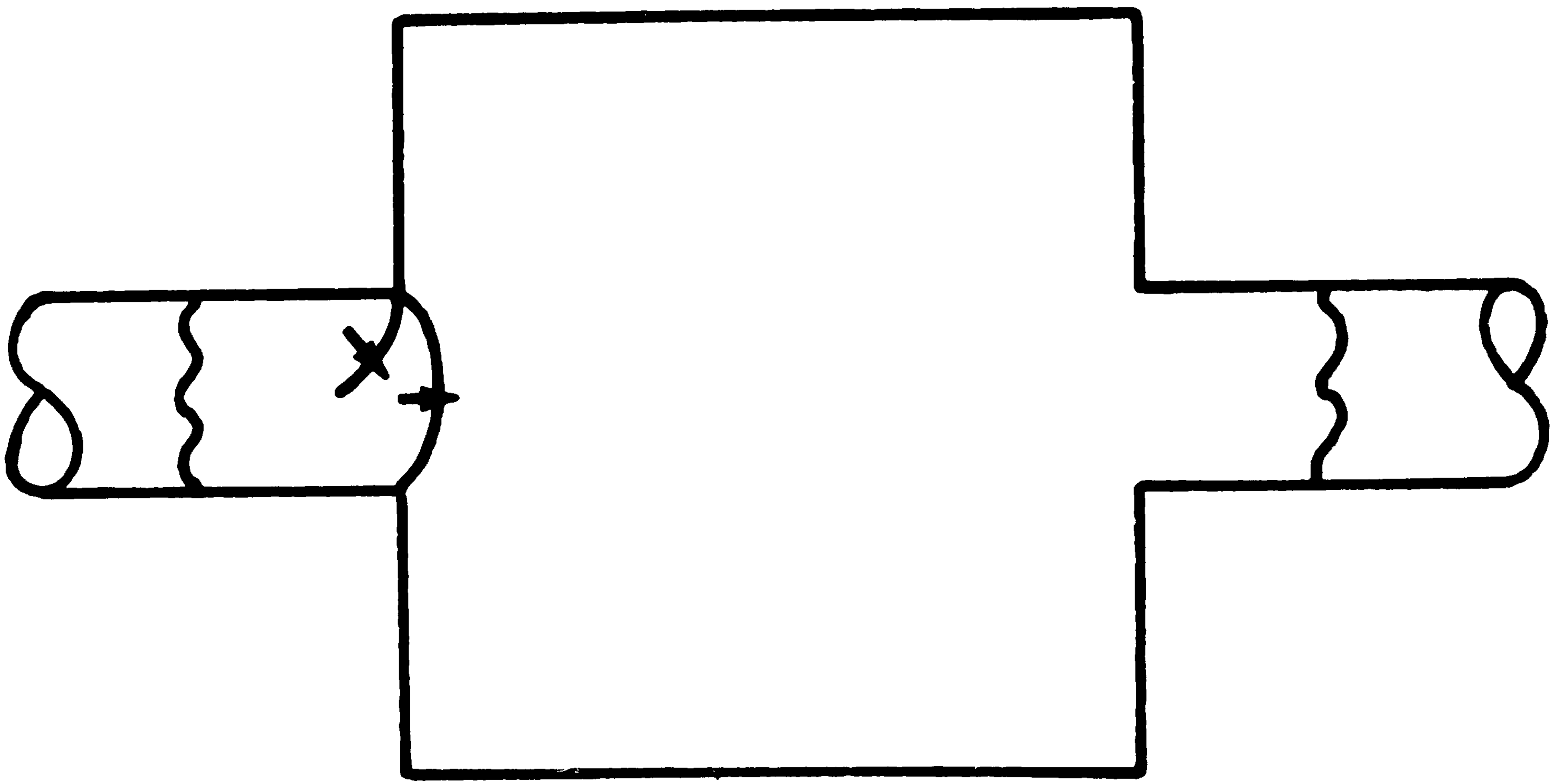


FIGURE 6. ''AQUARIUM'' TRAP

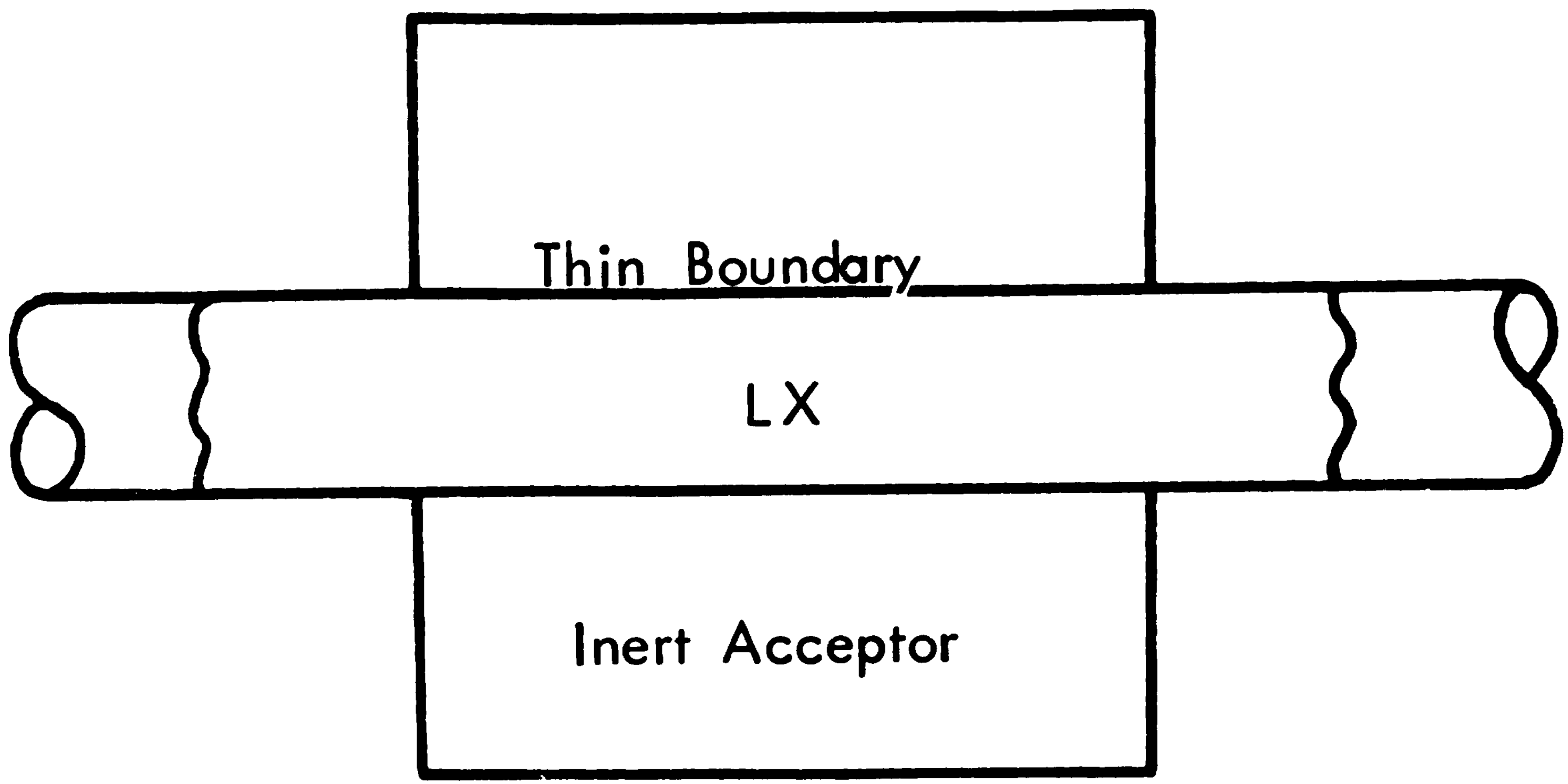


FIGURE 7. LINE SEVERING TRAP

With respect to the theoretical models of low-velocity detonation just mentioned, it appears that more than one may be valid, which for a particular case depending on the charge parameters. Therefore, more than one may have to be utilized in a detonation trap. It seems possible, however, that enough of the requisite conditions for a detonation may be removed to be useful for detonation quenching.

5. Line-Severing Trap

An obvious "mechanical" method of stopping a detonation is the physical severance or disruption of the line carrying the liquid explosive. The oncoming detonation itself may be used to sever the line in an area it has not yet reached if two sections of line are brought into partial mechanical contact with each other (Figure 7). For example this may be done by bending the line back on itself in a "U", and separating the two arms with a suitable medium; proper attenuation of an initial shock induced by an entering detonation, as well as proper flow properties of the inert medium, should sever the opposite arm before the detonation itself reaches the severed section.

It is obvious that for this trap to be successful, the severing shock must not cause initiation of the unreacted explosive. Therefore, as in the precompression trap, selection of the correct geometry and materials is critical.

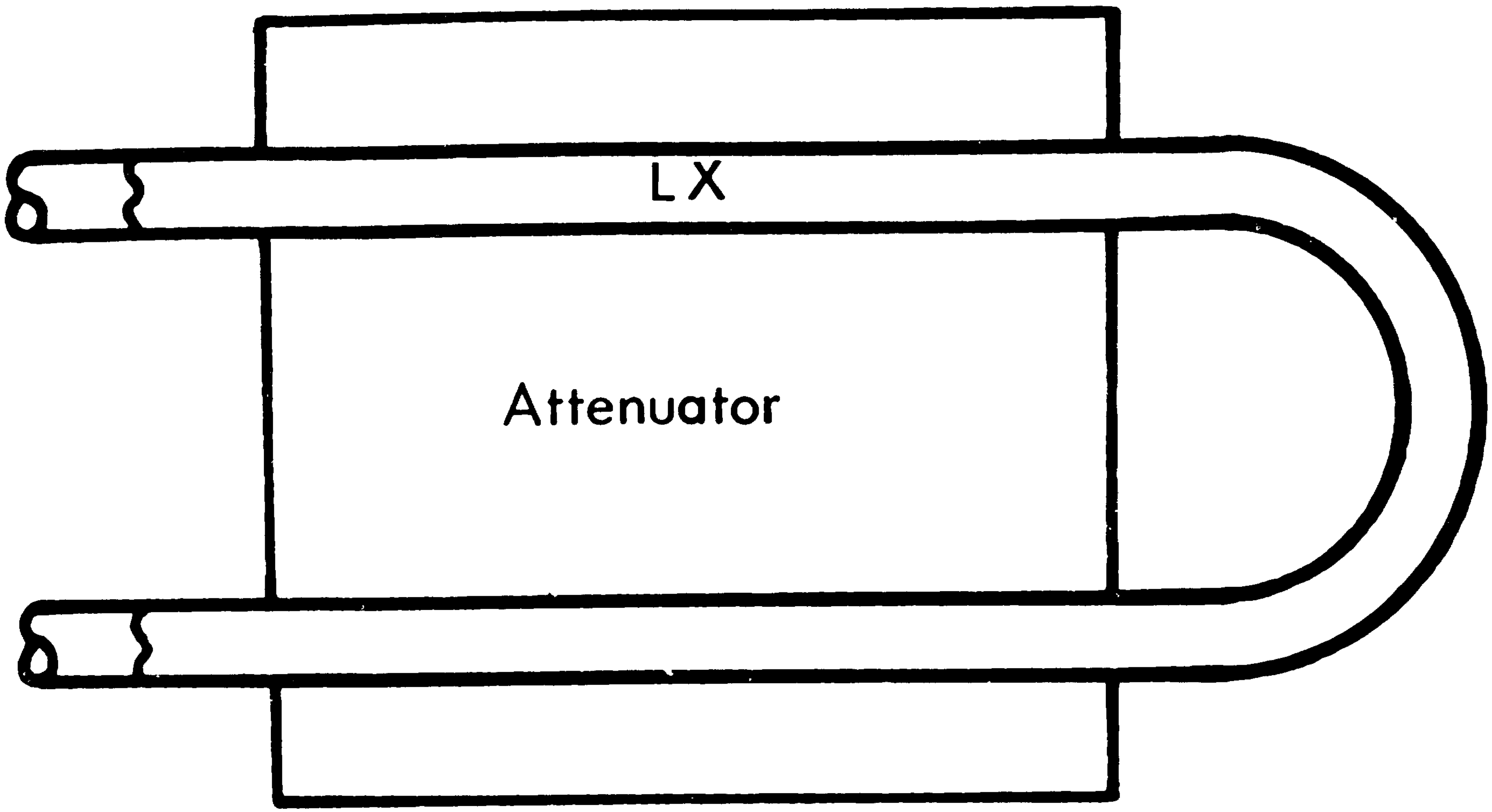


FIGURE 3. COMPRESSION DETONATION TRAP

Another method of severing the line is the loop type trap. (Figure 8) Here, the line crosses over itself in 270° or 360° bend. There is no special attenuating medium, but the line sections at the crossover point may be separated by an air gap. This trap has been tested with monopropellants successfully. (Table II) There is some question as to the exact mechanism of operation in the loop trap; a combination of precompression and severing may occur.

6. Externally Activated

As a final category of detonation trap, the externally-activated trap might use any of the number of mechanisms of operation, but the salient feature is the use of an external electronic circuit (Figure 9), with sensors placed along the explosive line some distance from the trap. A detonation would cause the sensor, through appropriate amplifiers, to trigger the trap before the reaction arrives. Any fast mechanical disruption of the liquid explosive line could be used here, such as high pressure injection of diluents, fast separation valves, or severing of the line. (Figure 10)

A serious problem with this type of trap is the rather short action time available due to the high propagation rates of detonations. For example, a sensor-to-trap distance of 100 meters (328 ft) would allow 50 ms. total action time for a typical LVD and 14.3 ms. for a typical HVD. For a distance of 10 meters (32.8 ft) these times are only 5 ms. and 1.43 ms. respectively. Obviously, for this type of

FIGURE 8. DIAGRAM OF 270'' LOOP DETONATION TRAP

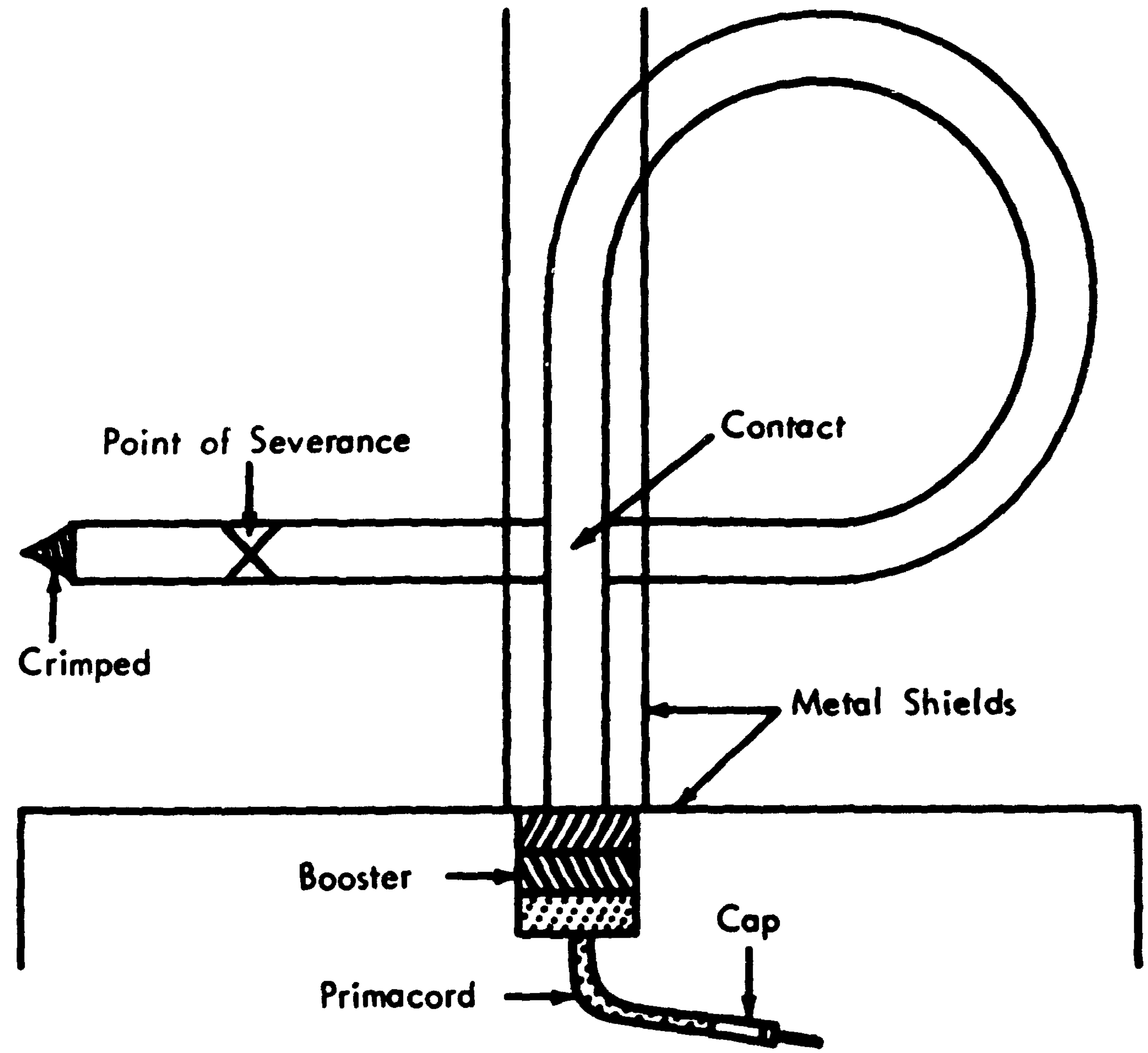


FIGURE 9. SENSING SYSTEM FOR EXTERNALLY-ACTIVATED TRAP

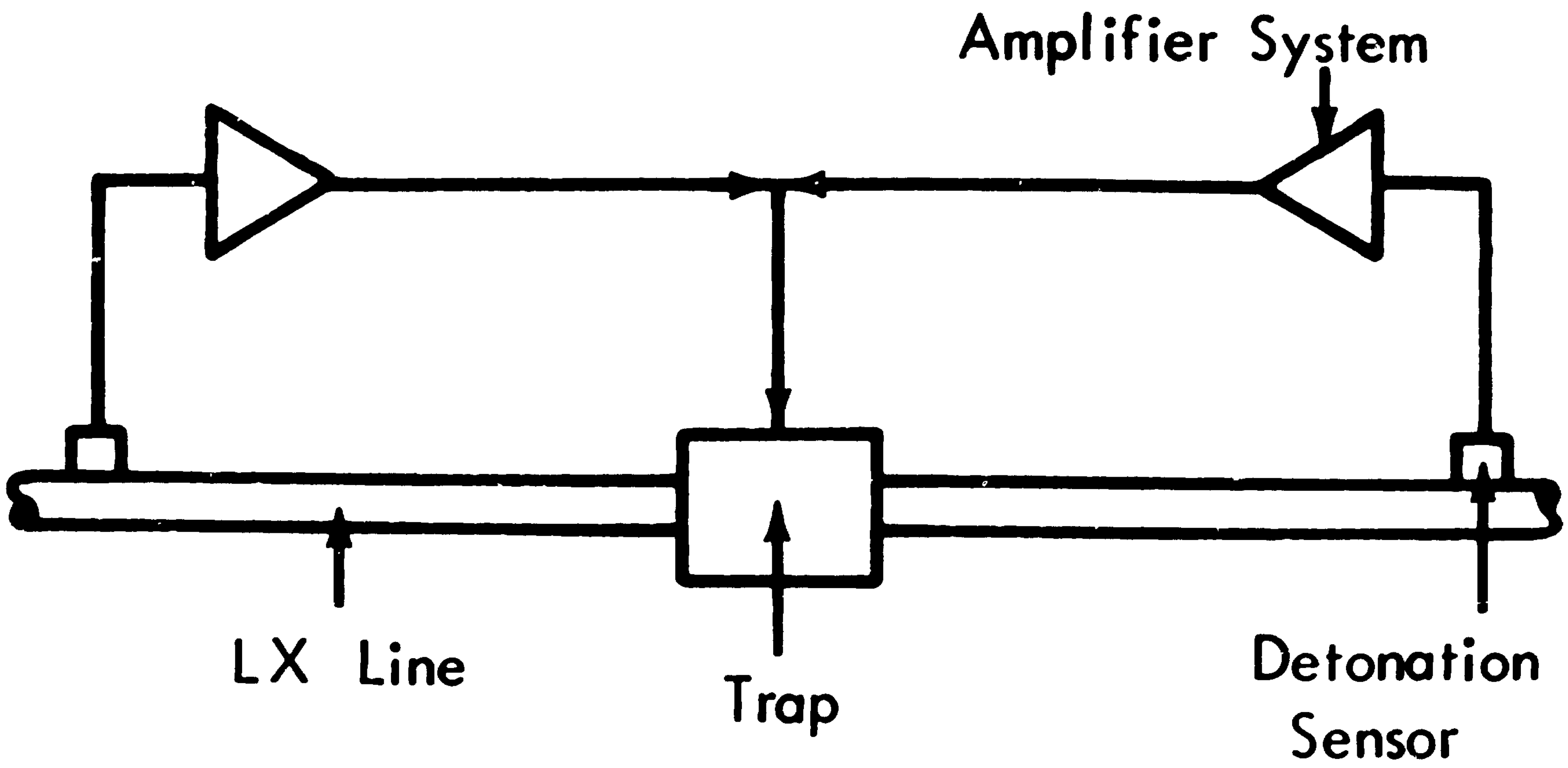
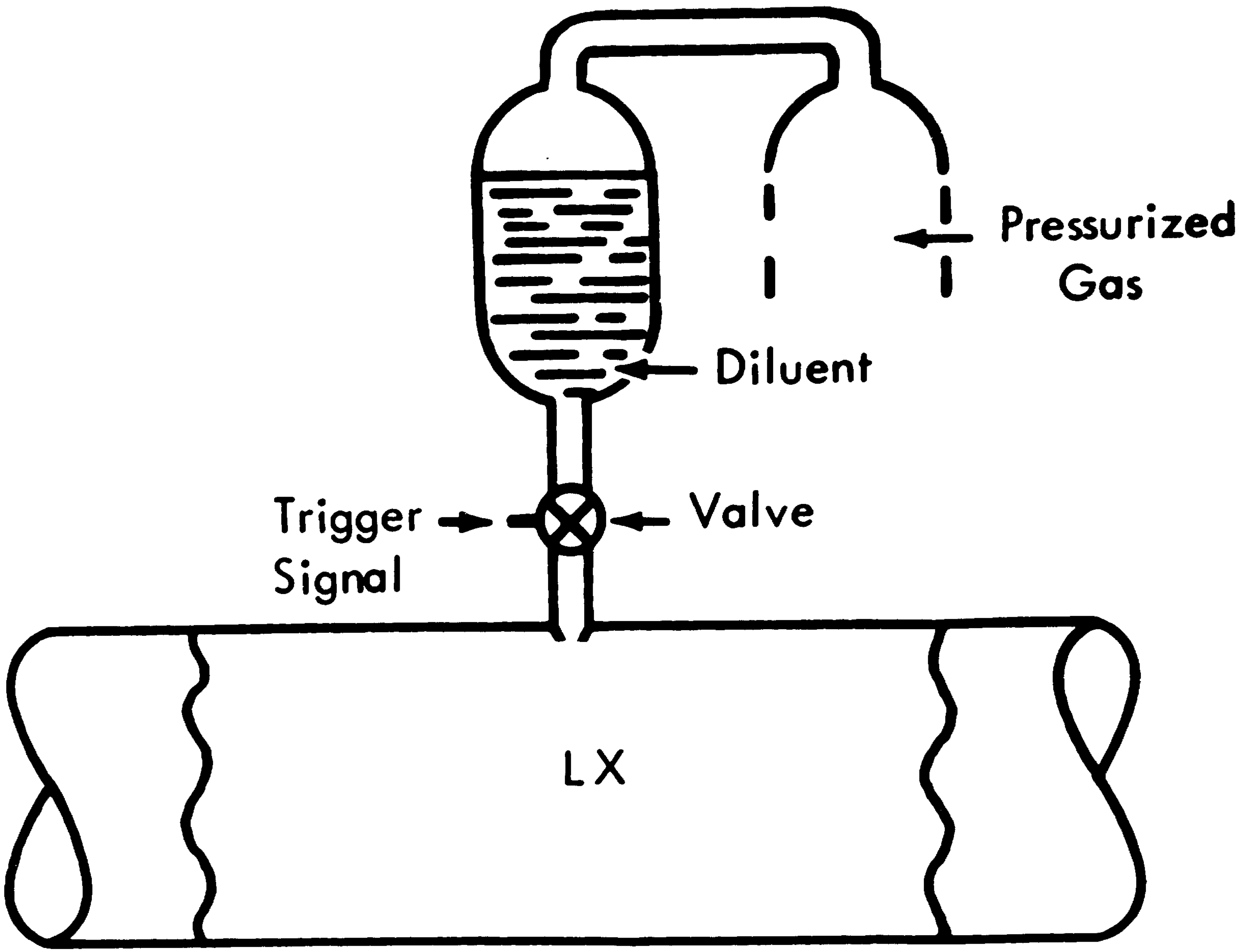


FIGURE 10. AN EXTERNALLY ACTIVATED TRAP



trap to be useful, either extremely fast mechanical devices must be used, or fairly long transfer lines.

In summary, there are definitely a variety of theoretical and practical ideas which could be used in the design of a useful detonation trap. In addition, actual test results for various types indicate a high probability that a practical device which would effectively and reliably quench on going detonations is possible.

REFERENCES

1. Grelecky, C., National Safety News, July 1967, P. 53
2. Personal Communication Bureau of Mines, Pittsburgh Mason, Ch.
3. Watson R.W. et.al., 4th ONR Detonation Symposium (1965) p. A-121
4. Dale, C., B, & Kennedy, H., C., The ASESB Meeting August 1965, P. 120
5. Gibson, F., Bureau of Mines, Explosive Research Center, Private Communication
6. Drimmer, B., Pat. No. 3,228,331/1966
7. Watson, R.W. t.al. 4th ONR Detonation Symposium (Oct. 1965) p. A-121
8. Zimmer, M., Combustion and Flame 12, 1-4 (1968)
9. Amster, A., et.al. 4th ONR Detonation Symposium, (Oct. 1965) p. A-146
10. Zimmer, M., 12th Symposium on Combustion, Poitiers 14-20 July 1968
11. Dremin, A. N. et.al., 10th Symposium on Combustion (1964) p. 839-40
12. Zimmer, M., et.al., unpublished work

ELECTROMAGNETIC RADIATION HAZARDS

TO ELECTRICALLY INITIATED ITEMS

Moderator: Anthony Sliwa
Naval Ordnance Systems Command
Washington, D. C.

HAZARDS OF ELECTROMAGNETIC RADIATION TO ELECTRICALLY INITIATED ITEMS

SUMMARY

This session was opened by Mr. A. F. Sliwa of the Safety Division of the Naval Ordnance Systems Command. He described the origin of the problem of hazards of electromagnetic radiation to electrically initiated items which is referred to in the Navy as HERO:

Hazards of
Electromagnetic
Radiation to
Ordnance

This problem arises from the ability of electrically initiated explosive items, often referred to as electro-explosive devices (EED's), to act as radio frequency (RF) antennas. Under the right conditions, these devices can pick up sufficient RF energy to be accidentally initiated by radiation from communication and radar equipments.

RF hazards have been known to exist both aboard ship and at shore stations for a number of years. Personnel have experienced electrical shocks and observed sparks and premature ignition of EED's as a result of RF energy radiated from high power transmitting antennas.

The problem was officially recognized by the Navy in 1958 when the Navy's Bureau of Ordnance started the HERO program and the prime factors, namely, high power RF equipment, have been increasing ever since.

To insure safety and reliability of ordnance systems and devices in an electromagnetic environment, the Navy sponsors, under the HERO Program, weapon design consultant services, and an extensive ordnance testing program at the Naval Weapons Laboratory, Dahlgren, Virginia, to determine weapon susceptibility to RF energy. These tests are conducted at typically maximum RF field levels encountered in the Fleet. The test conditions duplicate actual handling and loading situations under similar shipboard conditions.

To better understand the HERO problem, a detailed review of an EED, its application and methods of shielding the EED from RF was given. The Navy's method of weapon evaluation utilizing percentage of maximum no-fire current detected during test was also described.

To inform the Fleet and weapon designers of HERO problems, the Navy publishes a Technical Manual, Radio Frequency Hazards to Ordnance, Personnel and Fuel, NAVORD OP 3565/NAVAIR 16-1-529, a Military Design Specification MIL-P-24014 (WEPS) and a design guide NAVWEPS OD 30393. At this session, a Navy HERO training film was shown which is used at training commands, to familiarize personnel with HERO problems and how to avoid them.

Discussion:

Mr. Alfred Simon of Custom Materials, Inc., asked a question about what is being done about bare EED packaging to prevent a HERO problem. Mr. Sliwa stated that the only method of protection now used is to transport bare EED's in completely enclosed metal containers when the situation so warrants.

Mr. M. Balbaker, Marine Corps Base, Twenty-Nine Palms, California, asked whether NAVORD OP-3565/NAVAIR 16-1-529 gives a quick reference for EED hazard distance or weapon hazard distances from given antennas. Mr. Sliwa answered affirmatively. Mr. A. Grinoch of Picatinny Arsenal qualified the answer by further explaining the nature of EED's and stipulating that for a given item in a given situation, one cannot tell exactly what the problem is without testing. Mr. C. Cormack of the Naval Air Systems Command explained that the NAVORD OP-3565/NAVAIR 16-1-529 contains information only concerning the Navy's ordnance, and not that of the Army and Air Force.

Mr. George Hughes of NWS Yorktown asked about the relative hazards of AM communication equipment versus FM equipment. Mr. Sliwa answered that since FM is well above the 2-32 MHZ AM band, the hazard is less from FM as shown on the curves in the three Navy documents previously mentioned. In addition, AM transmission at the higher frequencies poses more of a problem than FM because the hazard must be measured in terms of peak envelope power whereas the FM hazard is in terms of average power.

Mr. H. C. Simpkinson of the Army Test and Evaluation Command asked a question regarding to what levels the Navy HERO tests are conducted. Mr. Sliwa referred Mr. Simpkinson to the environmental test levels of MIL-P-24014 (WEPS).

Mr. A. Grinoch of the Test and Evaluation Unit of Picatinny Arsenal described the Picatinny Arsenal Electromagnetic Testing Techniques.

Mr. A. Simon of Custom Materials asked what effect the reflectivity of the walls of the RF Hazard Simulation Chamber has on the uniformity of the field. Mr. Grinoch answered that there were no problems, because of the conductive walls of the chamber. The field is within $\pm$1db across a 20 ft. diameter.

LT. L. E. Ayer of NAD Oahu asked whether the Army has a radio frequency hazards manual, giving the susceptibility of various weapons. Mr. Grinoch replied that a manual is being compiled but none is yet available. Weapon susceptibility is now included in individual weapon manuals. At this time, Mr. Grinoch distributed a report of the studies conducted at Picatinny relating weapon susceptibility to the RF field. Mr. Cormack noted that the Army's nuclear weapons assurety group does compile RF hazards to all the weapons under their cognizance.

Mr. Cormack presented the RF hazard problems associated with the use of the 2.75 inch rocket when shipped in wooden shipping containers. His presentation is included as follows.

PICATINNY ARSENAL ELECTROMAGNETIC TESTING TECHNIQUES

by

A. Grinoch
Picatinny Arsenal
Dover, N. J.

Figure 1 is an artists concept of the work performed at the Picatinny Arsenal electromagnetic test facility.

Picatinny Arsenal has established a high powered test facility capable of evaluating the susceptibility of weapons to electromagnetic fields. This facility has call letters AA2XV, see Figure 1, and is authorized by the FCC to radiate over the entire spectrum with unlimited power.

Present capability allows certifying military systems to radiated fields in accordance with the specifications established by the Adjutant Generals Office. Radiated test fields are available from 100 Khz to 16 GHz. From 100 KHz to 30 MHz 12 kw CW power is available; from 30 MHz to 350 MHz, there is 4 kw power CW. This transmitter can be swept from 2 MHz to 350 MHz and pulse or sine wave modulated from 10 cycles to 10,000 cycles. See transmitter in Figure 3. Figure 4 is radar transmitter which covers the range from 350 MHz to 10,400 MHz. This entire range can be frequency swept and modulated and has an average power output of 300 watts. Figure 5 is a picture of one of the high powered log period antennas that is used to establish the test fields.

It has been the practice at RF hazard test facilities to perform tests at discrete frequencies spaced as closely as is considered practical. Picatinny Arsenal has performed swept frequency tests on three different cables as shown in Figures 6, 7 and 8. Figure 6 shows a 90.5 foot balanced cable terminated in an instrumented detonator. The curve with the cable far end short circuited shows sharp resonances which could easily be missed by testing at discrete frequencies. The frequency of maximum response is half wave (taking into account the cable propagation constant). Open circuiting the cable far end decreases the amplitude of maximum response and shifts response frequencies. Figure 7 shows a similar response for a different cable. Figure 8 is a third type 50 feet in length. Using the same frequency range, this figure shows that maximum response is at the half wave resonant frequency. The Q of this cable is lower than the others and whereas the maximum response is less, the responses in general are considerably greater. Similar resonance phenomena has been noted in the microwave frequency ranges. It is intended to perform similar tests shortly on a complete weapon system.

An RF Hazard Simulation Chamber has been developed that is 42,000 times more efficient than an antenna for establishing high quality test fields from 3 MHz down; see Figures 9 and 10. Field intensities of 100 V/M can be established that are uniform over a 20 foot diameter and can have a 377 ohm impedance, or impedance greater than 4000 ohms; it can also establish a 266 ma/meter field with an impedance less than 40 ohms. It is estimated that shielding effectiveness measurements of 185 db can be performed in this chamber.

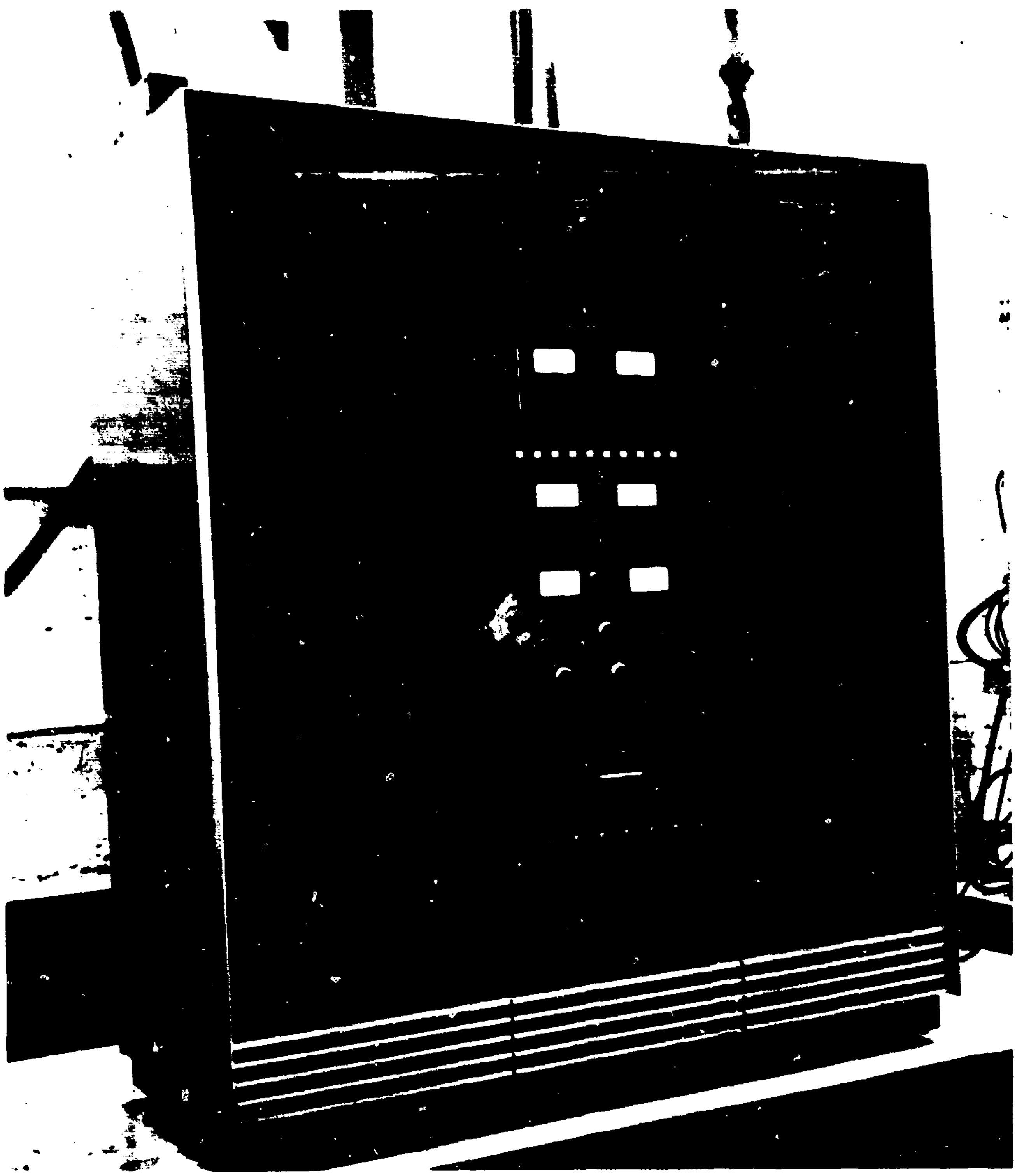
A 60,000 volt lightning simulator has been completed for evaluating the lightning susceptibility of components and sub-assemblies; see Figure 11. Tests using this system have recently started. While this simulator was being developed, tests were performed using CW techniques and a cable was developed that looks extremely promising; see Figure 12. Combined experimental and mathematical techniques are being developed for directly relating CW shielding effectiveness measurements to any arbitrary pulse waveship. This has application to both lightning and EMP and it is expected to make liberal use of the RF Simulation Chamber in this program.

A wide band noise generator has been built for evaluating the shielding effectiveness of cables connectors and other small components, see Figures 13 and 14. E and H fields have been measured within the box from 10 Hz to 16,000 MHz, and a report on the generator is in process. The wide band noise generator has been found to be particularly useful in evaluating proposed RF fixes for weapons under test. Its primary advantages are the ease and speed with which data can be obtained and a relatively unskilled person can perform these tests.

\- - - - - - - - - - - - -

FIELDS ACTING AGAINST WEAPONS
LIGHTNING
RADAR
DESIGN
EVALUATE
RETROFIT
SKILL·INGENUITY·EXPERIENCE


RF HAZARDS
TEST FACILITY



(U) PHOTOGRAPH
PICATINNY ARSENAL's HIGH FREQUENCY TRANSMITTER --
350 MHz to 10.4 GHz (500 watts CW)

FIG 4

(U) PHOTOGRAPH
PICATINNY ARSENAL'S LOG PERIODIC MONOPOLE
ANTENNA -- FREQUENCY RANGE 3 MHz to 50 MHz

FIG 5

RESPONSE OF 72Ω TRANS. LINE UNDER FAR FIELD CONDITIONS
(PARALLEL TWO WIRE LINE)

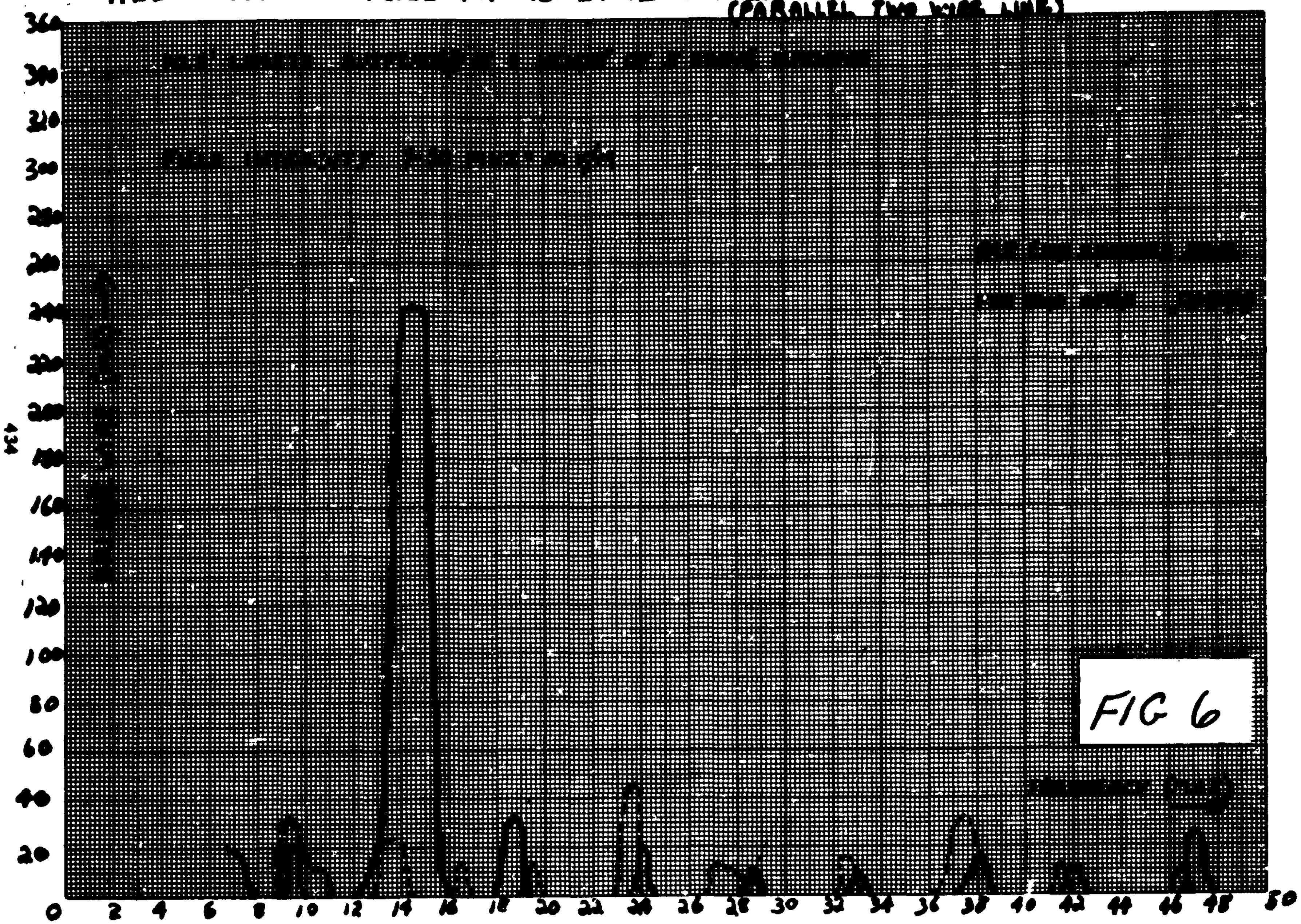


FIG 6

RESPONSE OF M-18 MINE WIRE CABLE UNDER FAR FIELD CONDITIONS
(PARALLEL TWO WIRE LINE)

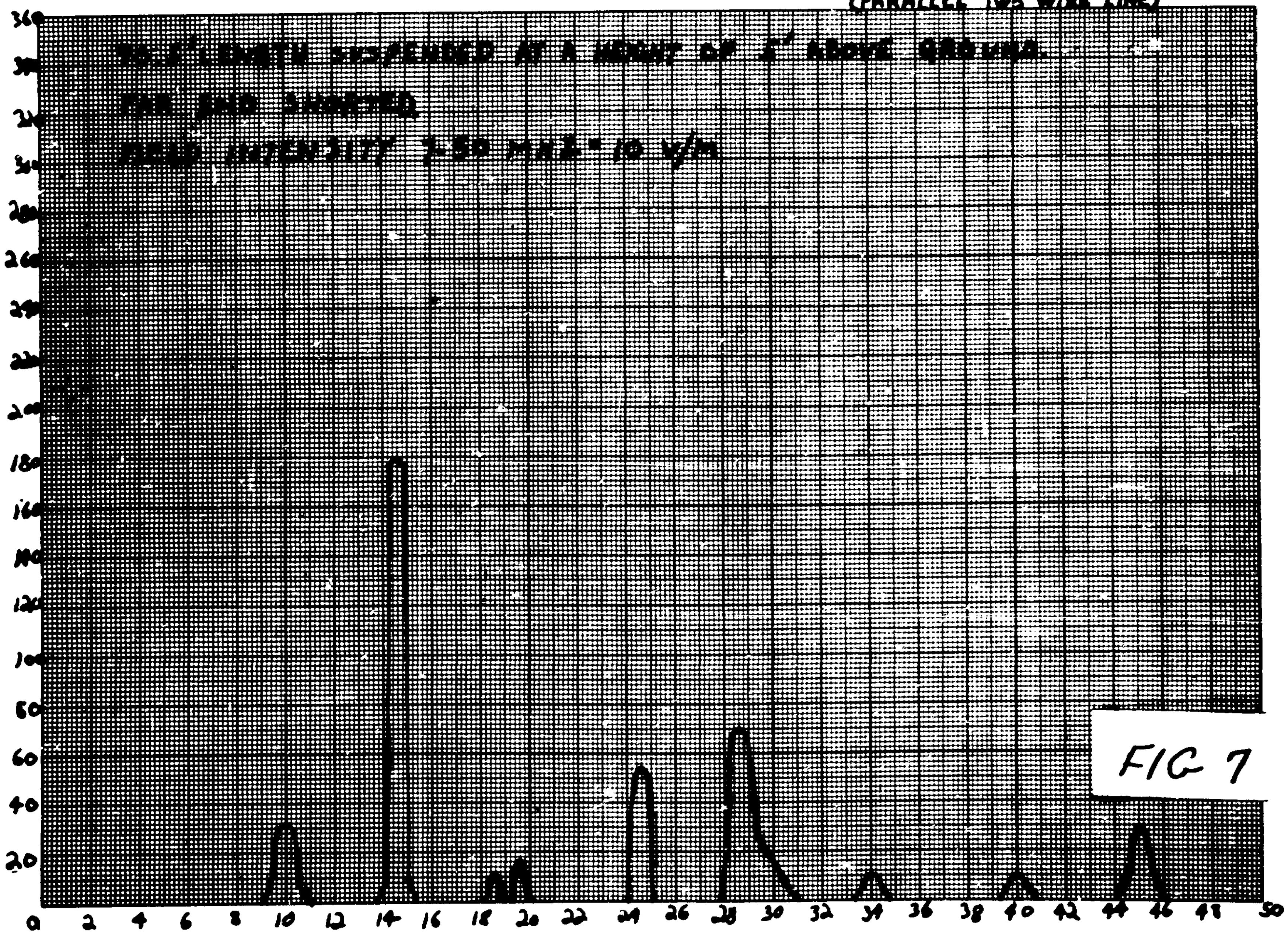


FIG 7

RESPONSE OF RED TELEPHONE WIRE (PARALLEL TWO WIRE LINE) UNDER FAR FIELD CONDITIONS

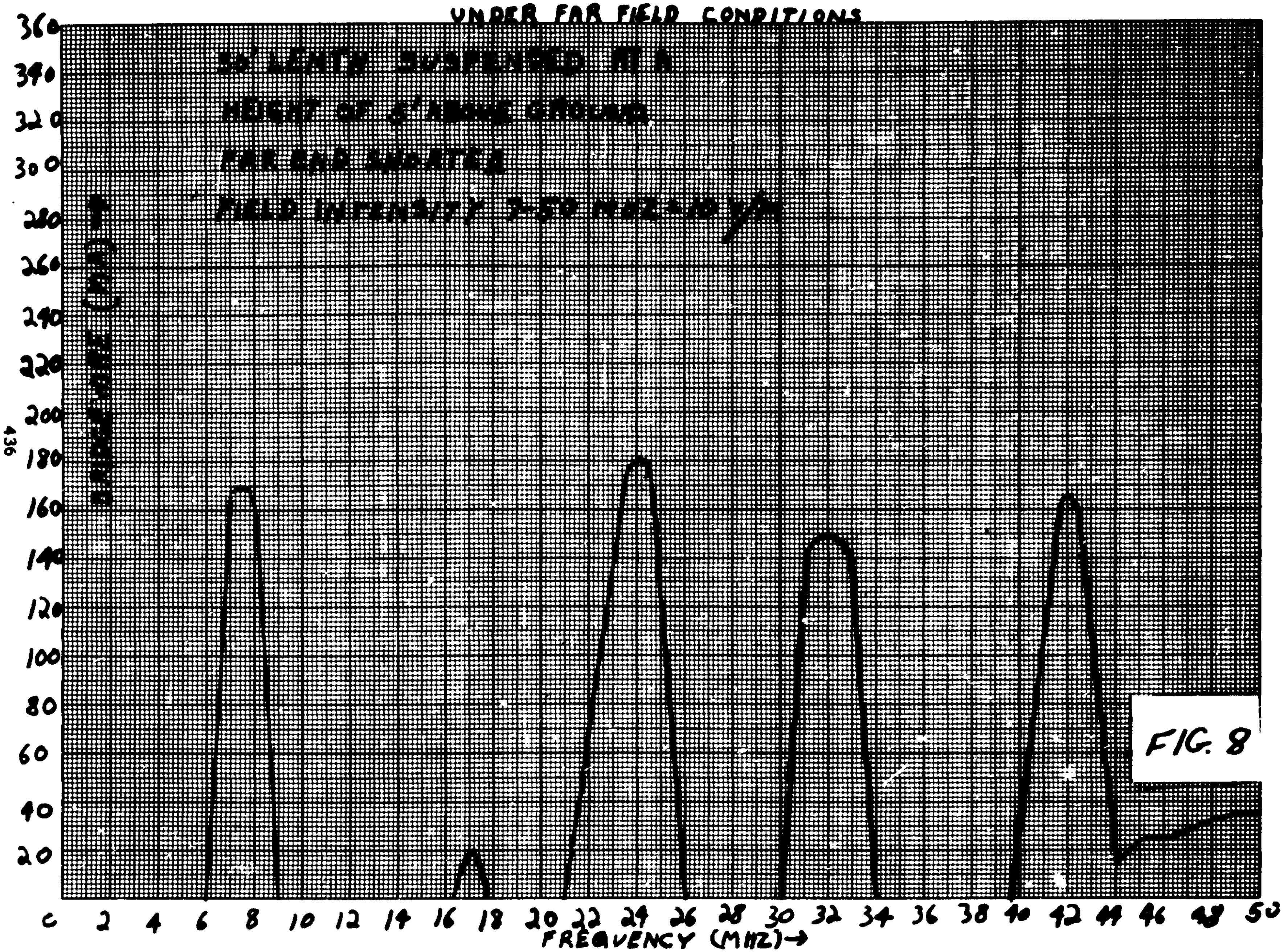


FIG. 8

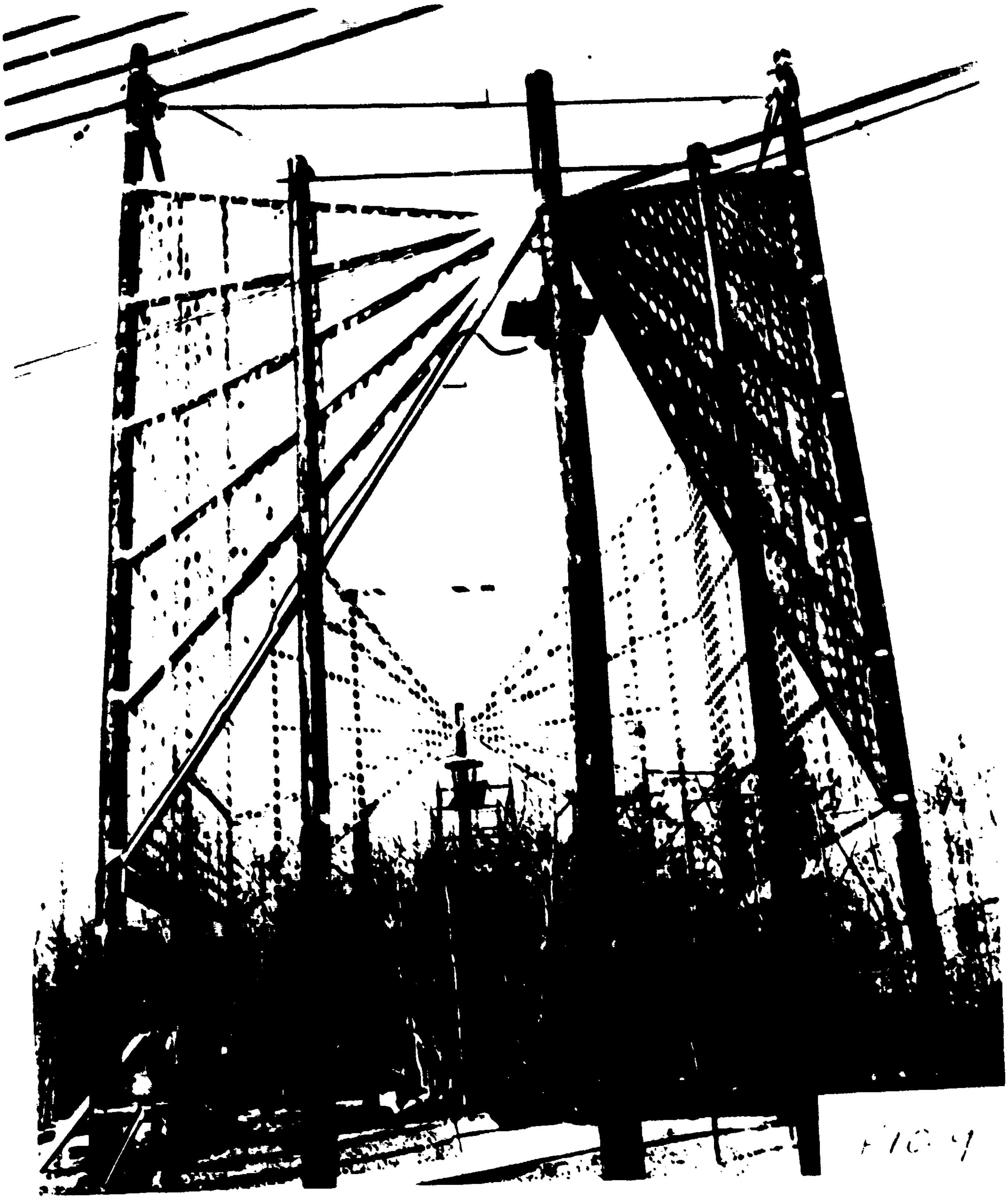
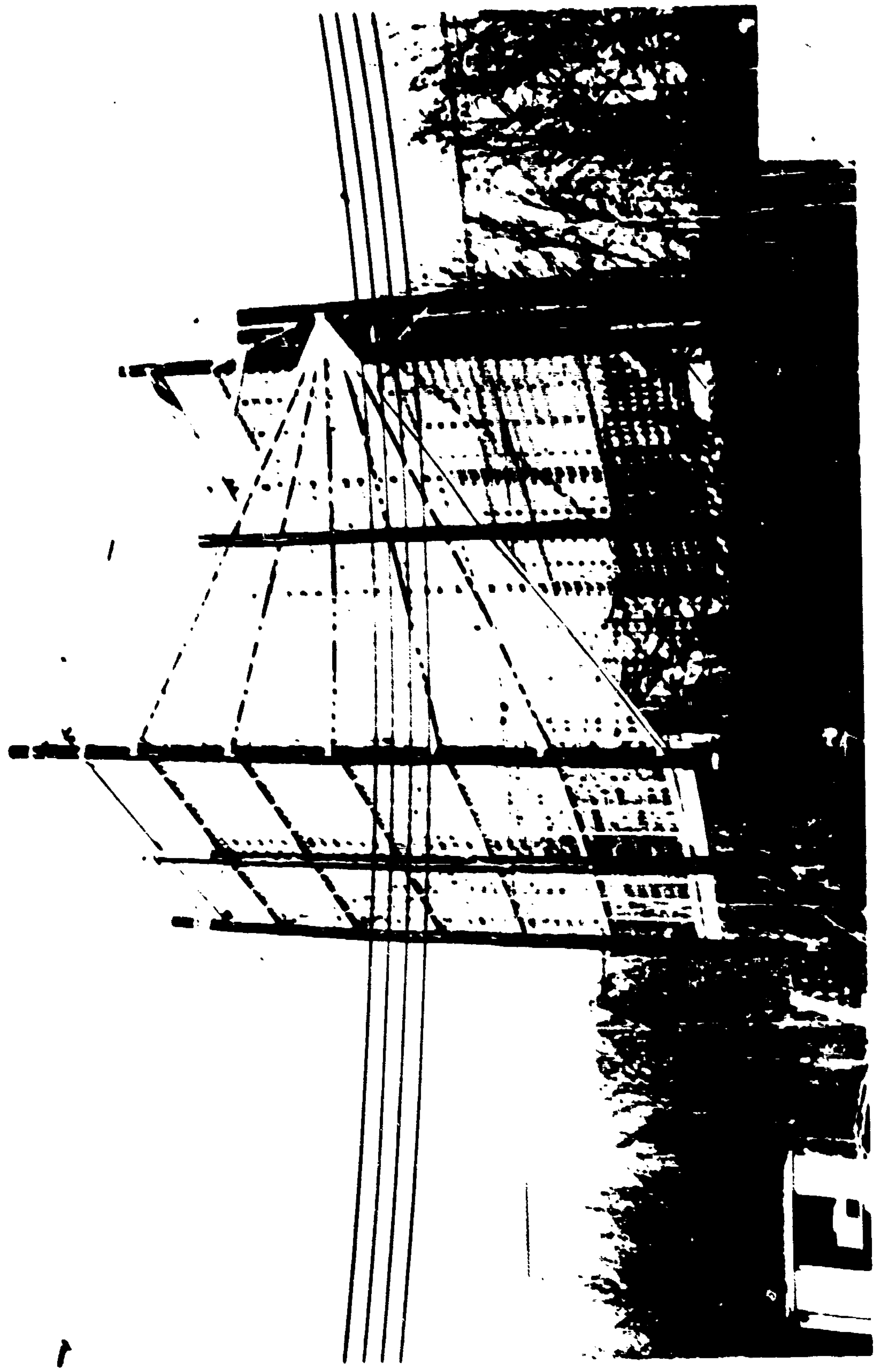


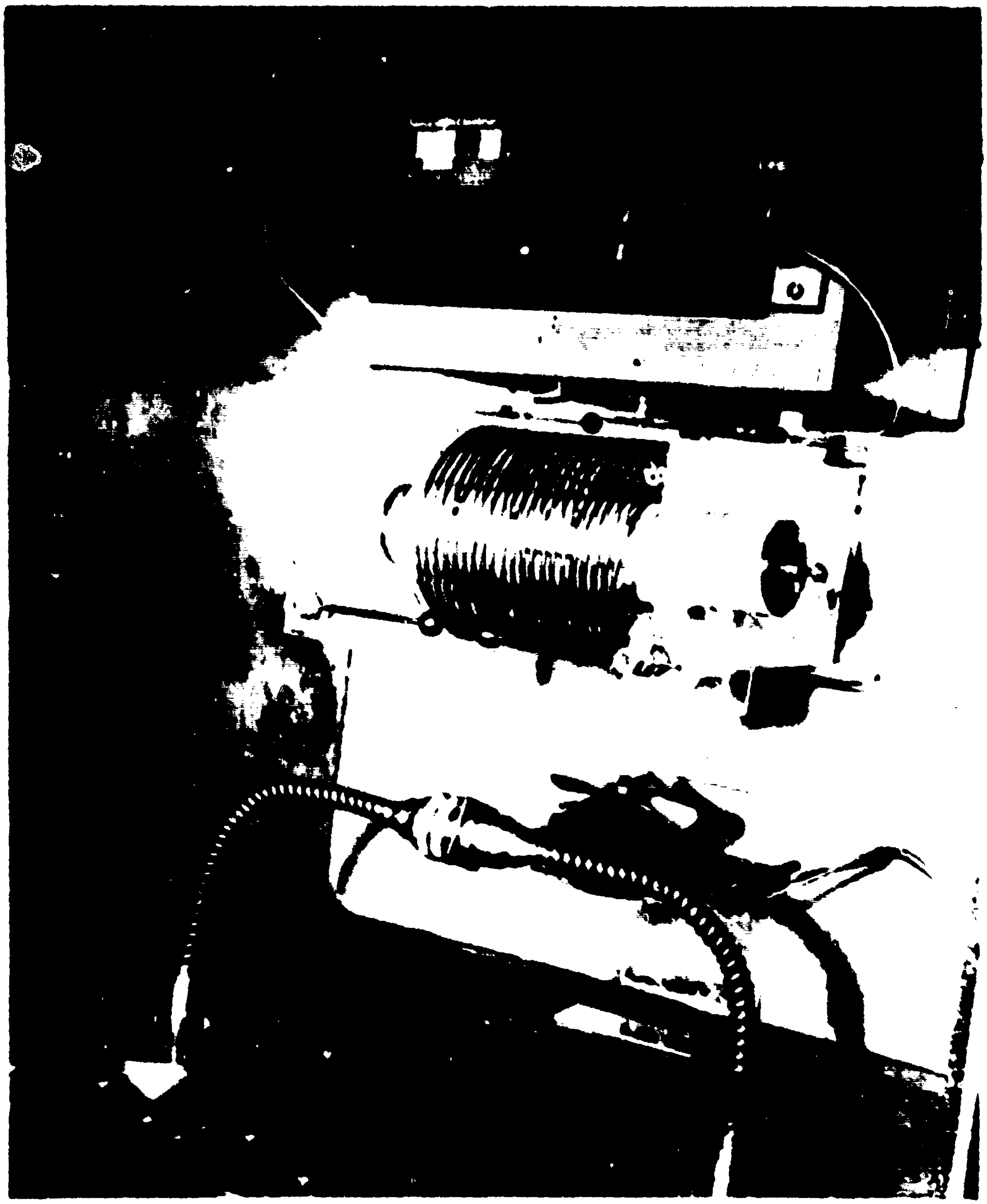
FIG 9



MAXIMUM ALLOWABLE SHIELD CURRENT FOR 200 MA. NO-FIRE DETONATOR CURRENT AND 500 VOLTS CONDUCTOR TO SHIELD

CABLE	TERMINATION OF FAR END	ATTN. db/100'	MAX SHIELD CURRENT FOR 200 ma DETONATOR CURRENT (AMPS)	MAX SHIELD CURRENT FOR 500 V CONDUCTOR TO SHIELD (AMPS)	COST PER FOOT
LIGHTNING SIMULATION					
RG 22B/U (ONE SAMPLE)	OC SC	126 101	400,000 22,000	— —	
SIMPLEX CABLE (POOREST SAMPLE TESTED)	OC SC	126 108	400,000 50,000	— —	
M18 MINE CABLE (ONE SAMPLE)	OC SC	— 70	— 632	— —	
RF SIMULATION (100 KHz)					
RG 22 B/U (ONE SAMPLE)	OC SC	108 77	50,000 1420	30,750	20¢ (IN SMALL QUANTITIES)
SIMPLEX CABLE (POOREST 100' SAMPLE TESTED)	OC SC	122 105	242,000 36,000	1,375,000	60¢ (IN LARGE QUANTITIES)
M18 MINE CABLE (ONE SAMPLE)	OC SC	89 30	5,600 625	11,220	5¢ (IN LARGE QUANTITIES)
INSTRUMENTATION SECTION CABLE DEVELOPMENT (RF TESTS - 100 KHz)					
	OC SC	137 113	1,490,000 40,000	>250,000	10¢

Fig. 12



RF HAZARDS DISCOVERED IN PACKAGING

by

C. M. Cormack
Naval Air Systems Command
Washington, D. C.

I would like to discuss the results of some recent tests on 2.75 inch Folding Fin Aircraft Rockets (FFAR) in a shipping container recently adopted for Navy use.

First, however, I would like to recall to your attention by a simple schematic drawing, the basic HERO problem. Figure (1) shows an Electro-explosive Device (EED) whose two leads are connected by wires in the weapon firing circuit in the form of a continuous loop. This loop, if exposed to high intensity RF fields, can have a voltage induced into it. Under certain conditions, the resultant current flowing through the load (EED in this case) may be sufficient to actuate the item.

Figure (2) shows a schematic drawing of the 2.75 inch FFAR with a shorting device included on all rocket motors which are shipped by means other than the rocket launcher type containers shown in Figure (4)a and (4)b. Note how the firing circuit drawn in equivalent circuit form in Figure (3) compares with Figure (1).

Now to the problem at hand. Until recently, the 2.75 inch FFARs were shipped to the Operating Forces in expendable launcher shipping containers such as the ones shown in Figures (4)a and b only. For training purposes at shore stations, launchers were reused. Replenishment rockets for these launchers were transported to the shore stations from Ammunition Depots in metal shipping containers.

Due to the increased use of rockets in Vietnam and the training requirements for both Navy and Air Force jet pilots, and Army and Marine helicopter pilots, wooden shipping containers have evolved. This wooden shipping container came to the attention of the HERO people when they began evaluating a change in the shorting device.

HERO tests on the rocket motor with new shorting device showed susceptibility to a particular radar frequency band. When the rocket was placed in a cardboard tube and in a wooden container, the RF susceptibility was unchanged as could be expected since wood and cardboard do not significantly impede RF energy.

In the hope of salvaging something out of the modified shorting device/wooden box situation, the rockets were tested with the old shorting device with the thought that these devices would provide adequate protection either alone or in wooden boxes. Unfortunately, however, such was not the case and restrictions on the use of wooden containers in high intensity RF fields of the frequency in question have had to be invoked.

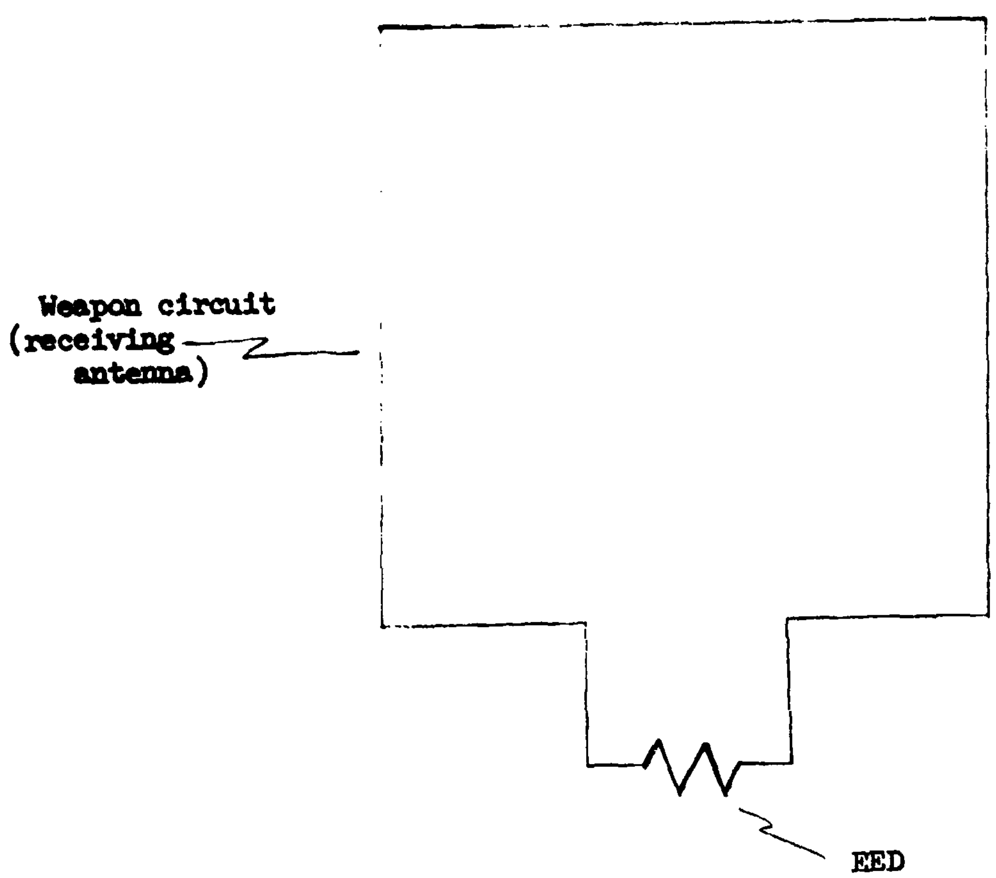


Figure (1) - Schematic of Weapon Firing Circuit Acting as Loop Antenna

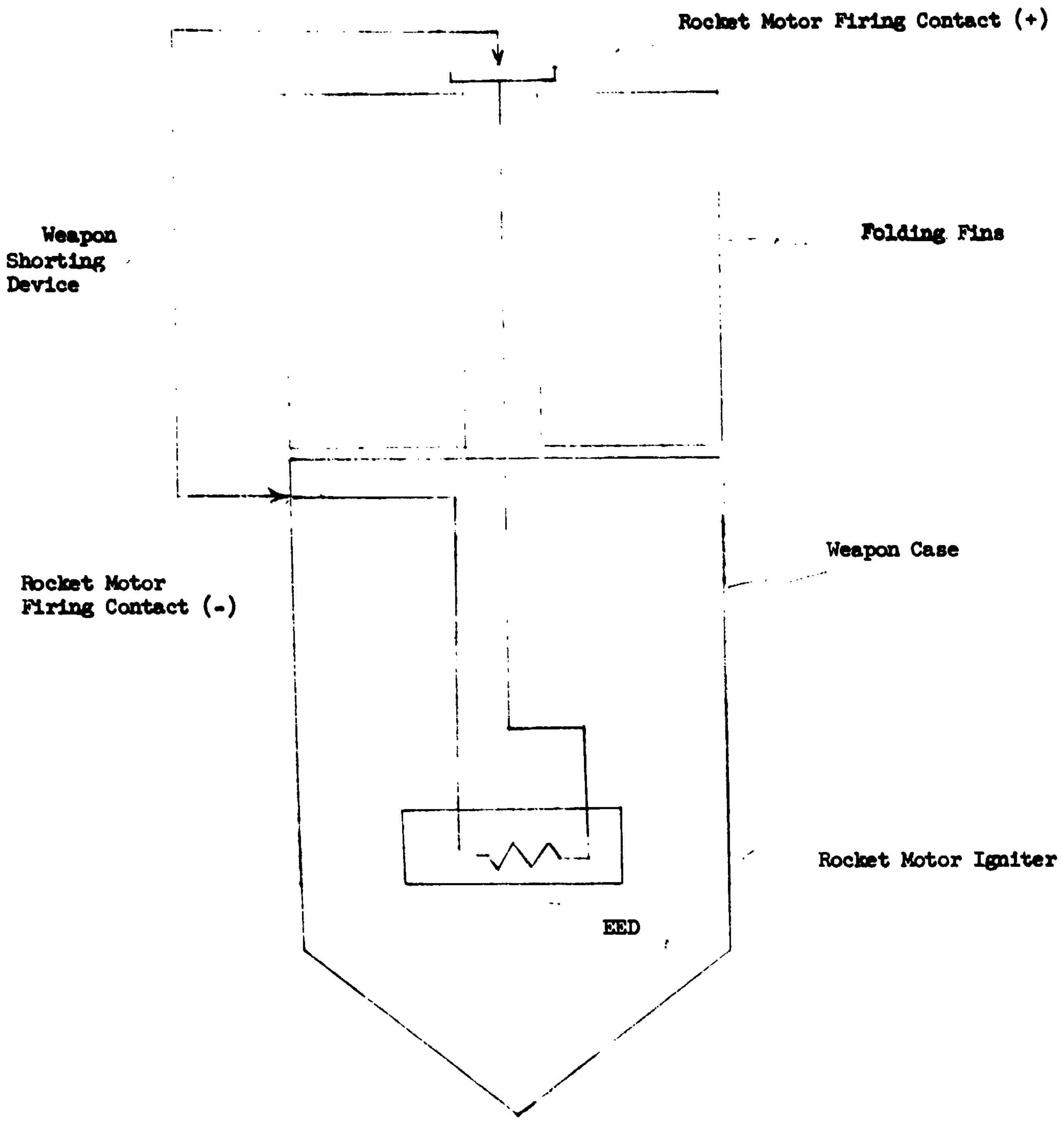


Figure (2) - Rocket Motor Schematic Diagram

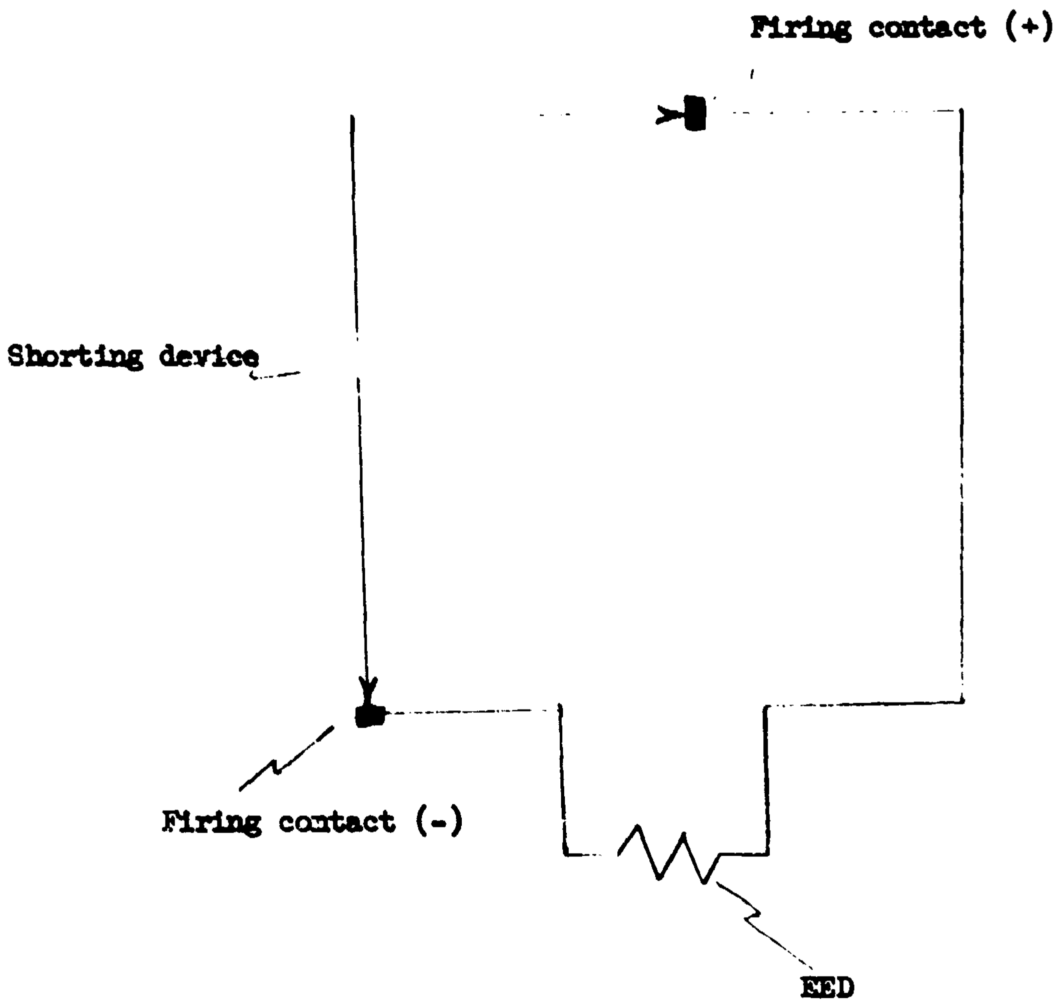


Figure (3) - Equivalent Circuit of 2.75 inch FFAR as Loop Antenna

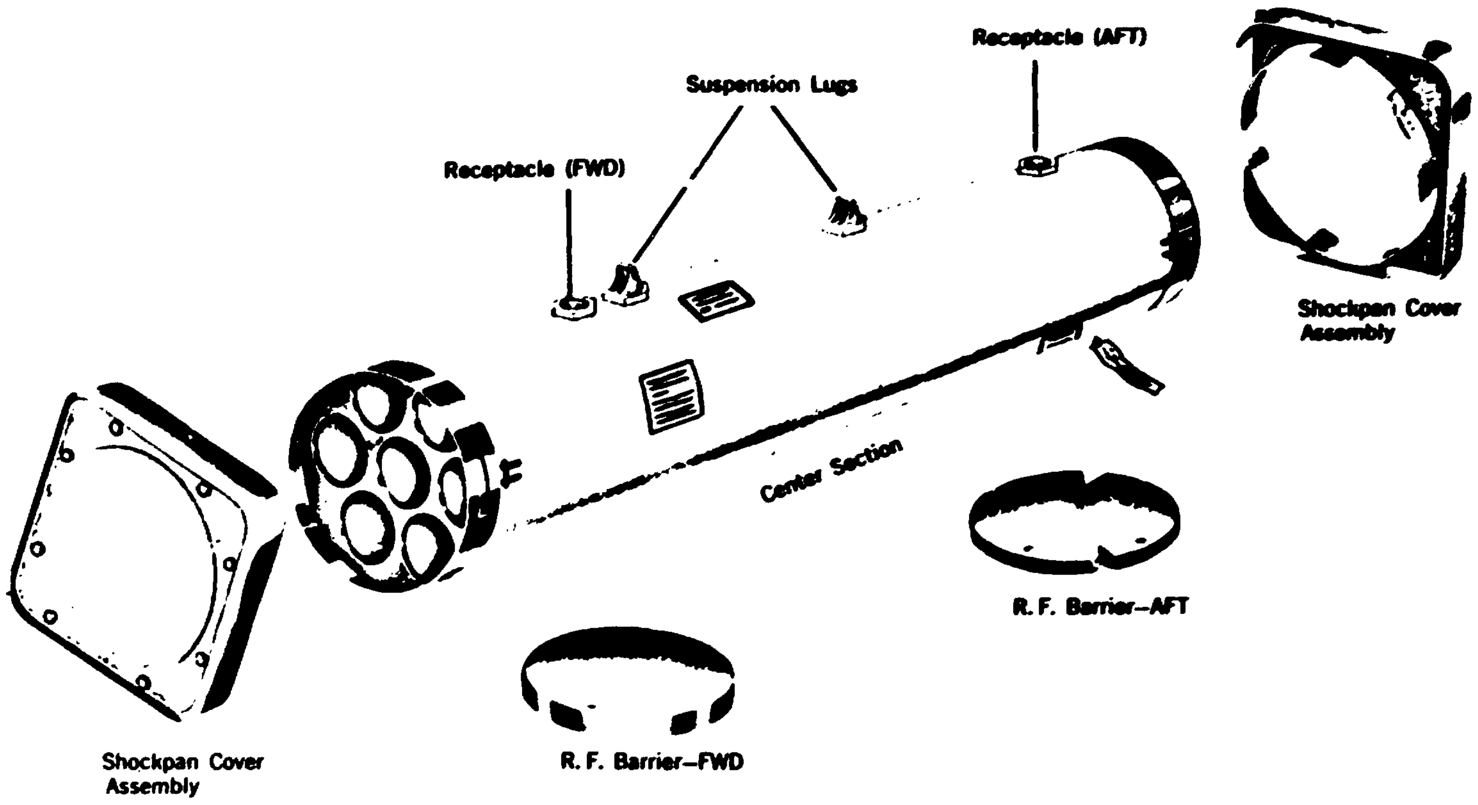


Figure (4)a - 7 Round Expendable Launcher Shipping Container for 2.75 Inch FFAR

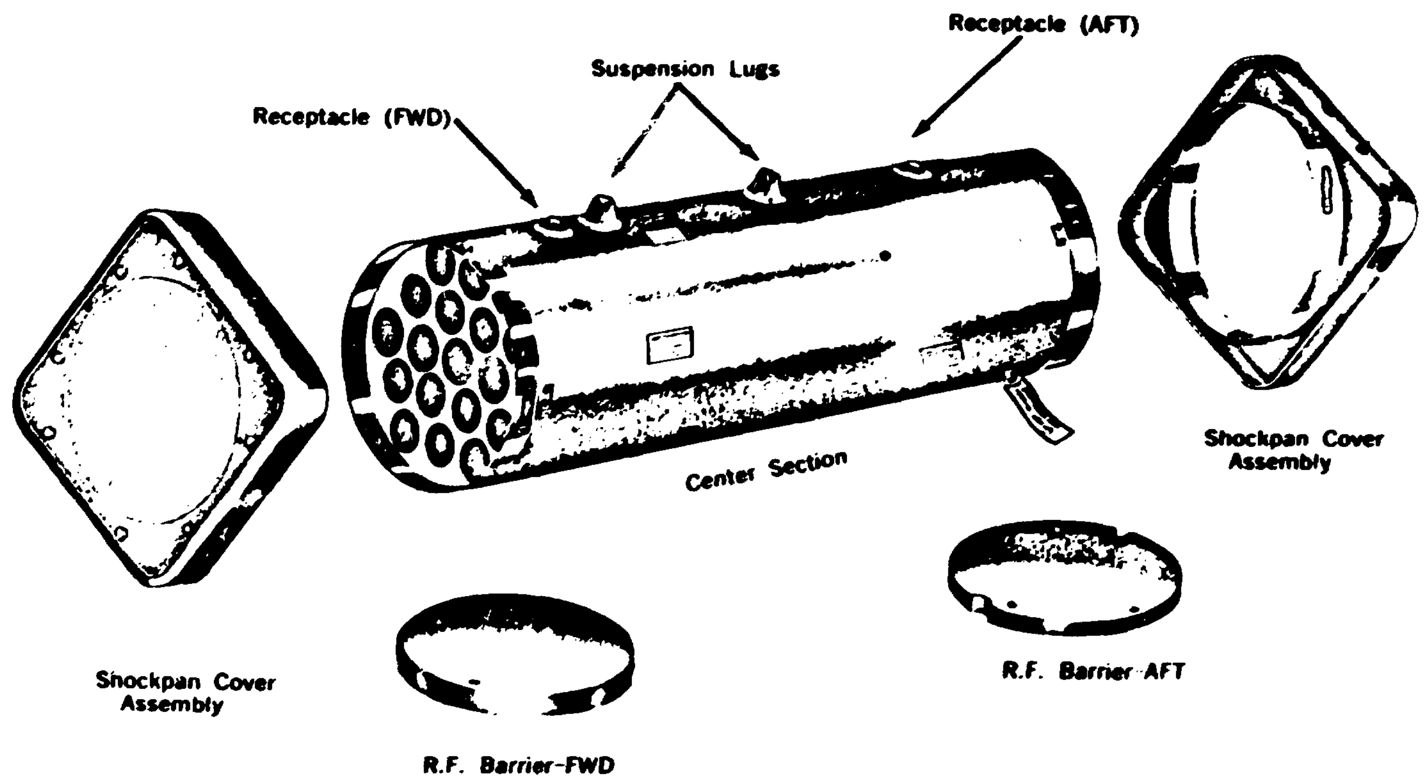


Figure (4)b - 19 Round Expendable Launcher Shipping Container for 2.75 Inch FFAR

AIR TRANSPORTABILITY OF AMMUNITION & EXPLOSIVES

AND SAFETY PROBLEMS

Moderator: F. M. Ashcraft
Military Airlift Command
Scott Air Force Base, Illinois

AIR TRANSPORTABILITY OF AMMUNITION AND EXPLOSIVES AND SAFETY PROBLEMS

SUMMARY

Informal presentations were made by Mrs. Shirley Sturtz, Hq AFLC and Mr. F.M. Ashcraft, Hq MAC. The group discussed the large number of explosives and other dangerous articles shipments being frustrated at aerial ports. It was pointed out that inspectors at aerial ports have instructions to inspect cargo for compliance with AFM 71-4/TM 38-250/NAVAIR 15-03-500/MCD P 4030.19/DSAM 4145.3 and to frustrate shipments that do not comply. It was suggested that shippers place more emphasis on properly packaging cargo prior to being offered for air transportation. It was further suggested that more emphasis be placed on insuring DD Forms 6 are initiated for each improper shipment and corrective action is adequate to prevent recurrences.

Inaccurate packaging information in technical publication was discussed. An example was TM 9-1325-209-50/T.O. 11A1-5-17-7. This publication lists an incorrect item name "Explosive Bomb(s) (WP)" on page 1-16; incorrect DOT markings "D.O.T. CLAS EXPL BOMB", on page 5-6 and incorrect marking "NOSE END" on page 5-6. This publication also identifies improperly designed containers (Lack of 360° forklift time enclosures) discussed in the Ammunition Packaging Problems and Materials Handling" Seminar. Respective services were requested to insure accuracy of technical data.

EXPLOSIVE ACCIDENT INFORMATION

DISSEMINATION AND RETRIEVAL

Moderator: LCDR J. E. Biron, USN
Naval Weapons Laboratory
Dahlgren, Virginia

EXPLOSIVE ACCIDENT INFORMATION DISSEMINATION AND RETRIEVAL

SUMMARY

1. The specialist session on "Accident/Incident Information Dissemination and Retrieval" was conducted as scheduled on 14 August 1968.

2. A lively discussion was held which indicated the strong and varied interests in this area. Unfortunately, the half hour lost because of the tour schedule reduced the useful output of this session.

3. Although no voting, per se, was conducted the session members were in general agreement on the following points:

a. There is a definite need for common reporting of explosive types of mishaps.

b. There is also a definite need for common definitions in this area.

c. The ASESB is the vehicle to carry these issues to the highest echelon necessary to take action to overcome these deficiencies.

d. The question of common safety tests specifications was not covered due to lack of time and the feeling that tri-service committees were making some progress in this field.

4. Session members recommend the following actions:

a. That ASESB initiate a recommendation to DOD that standard definitions in the safety area be drafted (or adopted) for use by safety or accident prevention organizations throughout the Federal Government.

b. That ASESB form and sponsor a committee to adopt a set of definitions for words peculiar to ammunition and explosives (their manufacturing, handling, loading, assembly, transportation, stowage and usage), not the least of which are "explosives", "munitions", and "ordnance".

c. That ASESB, once these definitions are established, inaugurate a program of explosive accident reporting that is:

(1) simple (probably in abstract form)

(2) widely, quickly and accurately disseminated

(3) available to all common users

(4) non-priviledged

(5) adoptable by all Federal agencies and acceptable to the private sector.

d. That ASESB include representation from the private sector in carrying out the above reccommendations.

e. That ASESB expand their efforts and charter to carry out these reccommendations if not so already chartered.

f. That ASESB give a status report on this matter at the next annual seminar.

LEAD AZIDE--MANUFACTURE & LOADING PROBLEMS

Moderator: Howard T. Scott
Director, Corporate Safety & Security
Atlantic Research Corporation
Alexandria, Virginia

LEAD AZIDE MANUFACTURING AND LOADING PROBLEMS

SUMMARY

Five papers were presented at the session:

Mr. B. Furini, E. I. duPont deNemours & Company, discussed "The Characteristics of Lead Azide and Manufacturing Techniques."

Messrs. J. Polson and H. Hanna, Mason & Hanger - Silas Mason Co., Inc., described an "Investigation of Static Electrical Phenomena in Lead Azide Handling."

Mr. L. Avrami, Feltman Research Laboratories, Picatinny Arsenal, discussed the "Impact Sensitivity of Lead Azide in Different Solid and Liquid Media."

Mr. B. Osborne, Atlantic Research Corporation, discussed "Fundamental Principles of Safety in Processing, Handling, and Loading of Lead Azide."

Mr. L. Jezek, U. S. Army Materiel Command, described recent accidents involving lead azide.

A copy of each of these papers follows.

The following points were made during discussion subsequent to presentation of papers:

1. It is safer to work with lead azide in the wet state than when dry, even though impact sensitivity may be greater when wet. Apparently, liquid significantly reduces the probability that an explosion will propagate.

2. The quantities of lead azide handled in conjunction with recent and present programs far exceeds quantities handled in years past.

3. Several serious accidents involving lead azide cannot be readily explained in the light of present knowledge. Additional investigation of the hazard characteristics of lead azide is needed.

RECENT ACCIDENTS INVOLVING LEAD AZIDE

by

Lou Jezek, Army Materiel Command

Laboratory Explosion

A lab technician was in the process of cleaning a crucible after performing an analysis to determine the weights of the component parts of an M41 mine. After the analysis was completed a brush was used for the cleaning operation. It was at this time that an explosion occurred.

Injuries -- lacerations and abrasions -- head, chest, and forearm.

The operation was changed -- ferric chloride will be used as an indicator for lead azide. In the analysis one of the steps involved the killing of lead azide with a solution of sodium nitrite and glacial acetic acid.

Scooping Lead Azide

Special purpose lead azide was being scooped from a conductive receptacle into cloth bags. While an operator was leveling a scoopful of dry azide under a leveling bar an explosion occurred.

Injury -- severe lacerations of thumb and index finger of right hand.

A study of the circumstances surrounding this explosion indicates that the cause may be attributed to the characteristics of special purpose lead azide. It is possible that this type of azide does not remain stable in crystal dimension. During storage or processing the crystaline structure may change and subsequently break during handling. This breaking action could generate sufficient energy to cause the azide to detonate. Will use Freon.

Screening Lead Azide

While pouring RD 1333 lead azide into a Sea Island Cotton Ballon Screen cloth by remote control, an explosion occurred.

No injuries.

Explosion caused considerable damage to roof, tile walls, and cello-glass blow out panels. Laboratory studies and tests will be conducted to determine exact characteristics of RD 1333 lead azide.

Explosion While Weighing Lead Azide

An explosion occurred while an operator was probably "spreading"

lead azide with a plastic spatula and applying Freon from a spray nozzle.

Injuries -- fatal one. Lost time 13.

No exact or most probable cause determined by investigating authorities.

Possible causes:

a. Impact initiation by dropping Freon spray nozzle or scale pan.

b. Electrostatic initiation from electric charge in Freon spray or on the person of the fatally injured employee.

c. Friction initiation from insertion of plastic spatula in the azide.

It is considered possible that a small amount of lead azide became dry at some undetermined location in the immediate work area; was initiated by impact, electrostatic discharge or friction and propagated to the Freon-wet azide.

<u>Initiation of Lead A by Impact</u>

Two incidents have been reported wherein lead azide crystals, while wet with Freon, were initiated by impact.

Both accidents involved the washing of metal type trays (boots) used in aerial mine manufacturing.

Two fatals; one injured.

<u>Other Accidents Involving Lead Azide</u>

1. While carrying a tray of azide (25 grams) the operator stepped or fell, the container was dropped; azide detonated. One injury.

2. After blending two pounds of lead azide by remote control two operators entered the blending bay. While in the bay an explosion occurred. Two fatals.

3. Brushing of azide on platen; explosion occurred. Loss of sight.

4. Two pounds of azide wet with Freon in Buechner funnel; knocked over; explosion occurred. Fatal one; injured three.

LEAD AZIDES

B. Furini, Jr.
E. I. du Pont de Nemours & Co.
Pompton Lakes, N. J.

Lead azide is one of the most important primary explosives in use today. It exists in several allotropic forms. The two most predominant forms are the alpha form which is orthorhombic and the beta form which is monoclinic. The alpha form is the stable modification and is the most common form. Alpha lead azide is normally prepared by rapidly stirring a solution of sodium azide with a solution of lead acetate or lead nitrate generally in the presence of a crystal modifying agent. Beta crystals can be formed by lack of agitation and in the laboratory they are prepared by slow diffusion of sodium azide and lead nitrate solutions through a layer of sodium nitrate solution. Beta lead azide has a tendency to revert to the alpha form on standing particularly if it is kept in water which contains a crystal of alpha lead azide. If it is kept in contact with a lead salt solution or at elevated temperatures, it will generally revert to the alpha form.

Lead azide was first prepared and identified in 1891 by Curtis. Practical use of lead azide in the explosives industry was implemented in France in 1907. However, the use of this

material for Military ammunition did not come into being at that time due to its erratic sensitivity to impact. Specifically, during the early development period, sensitivity was associated with large crystals and the beta form was thought to be extremely sensitive and not stable. Both of these basic assumptions have been subjected to some criticism. To overcome the problem of unpredictable sensitivity, dextrin was introduced as a nucleating agent and caustic (sodium hydroxide) was introduced to produce basic lead azide and thereby reduce purity. In 1930, dextrinated lead azide was introduced in this country and is still in use today for the majority of commercial and many Military applications. About 1951, a need for a more powerful lead azide became apparent due to a trend towards smaller detonators.

In the United States, several types of azide are either used or frequently discussed. They are as follows:

1. Service lead azide
2. Pure lead azide
3. Dextrinated lead azide
4. RD-1333 lead azide
5. "Special Purpose" lead azide
6. RD-1343 type lead azide

7. PVA lead azide

8. Colloidal lead azide

9. Dextrinated colloidal lead azide

<u>Service Lead Azide</u>

Service lead azide is not used to any extent in this country to my knowledge. This material was at one time the standard priming agent for British detonators and was used extensively in Canada. It has a purity of about 96.5% and contains some basic lead azide along with lead carbonate which is the nucleating agent. The lead carbonate is located in the nodal points of the crystal. However, the surface of the crystals are essentially pure lead azide and appears to be unaffected by the lead carbonate.

<u>Pure Lead Azide</u>

Pure lead azide (100% purity) is of use primarily from an academic standpoint. Actually, some write-ups indicate that any lead azide above 98% purity can be classified as pure lead azide. This material can be produced by the standard techniques of lead azide manufacture with the exception that the nucleating agent is deleted. Some of the experimental pure lead azides have been loaded into devices on a limited basis without difficulty. Even so, use of material produced without

a nucleating agent has been generally avoided because of uncertainties as regards safety during long term storage.

Dextrinated Lead Azide

Dextrinated lead azide has been in use in this country since 1930 and has a purity in the vicinity of 92.5 to 94.5% (96.5% in Europe). Recently, there has been an increased interest in obtaining material in the vicinity of 94.5 to 96.5% purity. Dextrin is used as the nucleating agent. It is water soluble and has the effect of rounding the edges of the orthorhombic crystals. It enters into the fundamental reaction to a limited extent but more importantly is trapped during crystal growth. Trapped dextrin contributes to the porosity of the crystal and the undesirable hygroscopicity properties of the dried material. Dextrinated lead azide is produced by the reaction of dilute solutions of lead nitrate and sodium azide.

RD-1333 Lead Azide

RD-1333 lead azide as produced in this country is an off-shoot of lead azide manufactured in Britain under the designation RD-1333 lead azide. Lead carboxymethylcellulose is used as the nucleating or agglomerating agent. It is co-produced simultaneously with the production of the lead azide. RD-1333's prime reason for existence is that it has a purity above 98.5% which, in turn, makes it desirable from

a Brisance standpoint. A goodly number of Military detonators are now using this compound. The use of lead carboxymethly-cellulose also imparts non-hygroscopicity to this product. The purity requirement for RD-1333 (98.5%) is a very difficult one to maintain and, in some instances, 98.0% purity appears to be more applicable.

RD-1333 lead azide is produced by a coprecipitation technique utilizing strong solutions of lead acetate and sodium azide. A weak solution of sodium CMC is used to produce lead CMC. Because of the inherent alkalinity of sodium azide, some basic azide is formed. The granules as produced are small crystallites imbedded in lead CMC. Type CMC, speed of agitation, temperature, speed of solution addition, addition technique, pH, solution concentrations and physical clearance of the agitator are quite important in the production of satisfactory granules.

RD-1343 Type Lead Azide

RD-1343 type lead azide is an off-shoot of the RD-1333 material. It is not in commercial production in this country. However, it has desirable characteristics in that it should be easier to produce and densities can be more easily maintained. Essentially, the two types of lead azide are similar with the exception that a significant quantity of sodium hydroxide is added to the sodium azide reactant solution in RD-1343 manufacture to reduce the finished lead azide purity by approximately 1%.

"Special Purpose" Lead Azide

"Special Purpose" lead azide is a form of RD-1333 lead azide and differs from this compound essentially in the type of Sodium CMC used as a nucleating agent. The type CMC used for "Special Purpose" was designed for improvement in the operating efficiency. In particular, it was designed to significantly increase the capacity of existing Government Plants by permitting a substantial reduction in reaction time and "turn around" time during production of the lead azide.

The variables associated with CMC that are responsible for this reduction in reaction time are known. The purity of this type of lead azide is approximately 98.5% minimum. In every respect "Special Purpose" lead azide is equivalent to RD-1333 lead azide with the exception of appearance. "Special Purpose" lead azide essentially is egg-shaped with slight modifications of this configuration whereas RD-1333 has a tendency to have a holly leaf type structure. Both compounds are poly-crystalline agglomerates of lead azide imbedded in lead CMC and are opaque with no clear crystalline material. An RD-1343 type lead azide could be produced by the "Special Purpose" technique by simply adding sodium hydroxide to the sodium azide solution.

PVA Lead Azide

PVA lead azide is produced by precipitation of lead azide

in the presence of polyvinyl alcohol in water medium. The purity of this compound is about 96.5%. PVA lead azide precipitates in the form of single crystals that are elongated. Because of the shape of crystals, there is some question of whether beta azide may or may not be present.

Colloidal Lead Azide

Colloidal lead azide is a fine lead azide with a particle size of 3-4 microns. It is produced using various techniques but without a nucleating agent. Colloidal lead azide is not acceptable for use where good flow properties are needed. However, it is ideal as a priming charge and for electrical initiation because of its fine particle size.

Dextrinated Colloidal Lead Azide

Dextrinated colloidal lead azide was developed as a substitute for colloidal in hopes of finding an explosive which would be suitable for use with bridge wire ignition in special electrical detonators. It was also hoped that the material would be less sensitive to shock than colloidal lead azide. However, this was not the case.

Added Comments

Basically, as the purity of lead azide decreases from 100% down to approximately 90%, the Brisance decreases accordingly. At about 90% or lower, marginal performance of lead

azides have been noted. However, most standard sensitivity tests indicate that fairly pure (98.5% purity) lead azides are somewhat more sensitive from static and impact sensitivity standpoints than the relatively impure lead azides (93.5% purity). There is considerable evidence that some added precautions are needed for the high purity materials. This is based on the theory that propagation from crystal to crystal increases significantly for the higher purity materials. Namely, a snap may occur with a thin layer of low purity material and not propagate to the awaiting mass nereby. Whereas, it is highly probable that a snap with high purity material might propagate to the nearby mass.

Precautions associated with lead azides include the whole realm of precautions associated with sensitive explosives. It is impact and friction sensitive and might be classified as being on the borderline of static sensitive (depending on the test source and type). Static sensitivity tests and data are being given a thorough scrutiny by various manufacturing concerns at the moment.

FUNDAMENTAL PRINCIPLES OF SAFETY IN PROCESSING, HANDLING, AND LOADING OF LEAD AZIDE

by

B. A. Osborne
Atlantic Research Corp., West Hanover, Mass.

Many accidents in the handling, loading, and processing of lead azide are caused by deficiencies in four major categories.

1. Energy concentrations
2. Lack of adequate facilities and design criteria
3. Lack of knowledge of the characteristics of lead azide
4. The human element

I am sure there are others, but I am going to comment briefly on each of these categories in that order.

1. Energy Concentrations

Energy concentrations such as sparks, friction, impact, flame, hot objects, chemical reaction and electrostatic discharge, cause accidents in the handling, processing, and loading of lead azide. It follows that if each of these energy producing elements are eliminated; we are well on our way in decreasing the probability of ignition from these sources. I am going to treat each of these energy producing sources individually.

A) Sparks

Eliminate all sources of mechanical and electrical sparks by the use of proper nonsparking tools and approved electrical systems and devices.

B) Friction

Eliminate sources of friction such as dragging objects over benches and table tops. Eliminate hand scooping and pouring insofar as is practical.

C) Impact

Eliminate sources of impact such as dropping or dropping objects into or striking against.

D) Flame

Eliminate all sources of flame in areas where lead azide is handled, processed, or loaded, such as cutting torches, welding equipment, bunsen burners.

E) Hot Objects

Eliminate contact with sources of heat far below its ignition temperature, such as with soldering irons, hot plates and electric ovens with open elements.

F) Chemical Reaction

Eliminate all sources of contact with incompatible metals, chemicals and concentrated acids which could raise the temperature to the ignition point.

G) Electrostatic Discharge

Eliminate all sources of electrostatic discharge by proper bonding and grounding of equipment, benches, floors, etc., by wearing of proper clothing, conductive footwear, and the use of humidification from 50 to 60 percent R.H. or better where the process permits. Use conductive trays, containers, and receptacles, and avoid drying lead azide by forced circulation of air through the lead azide.

2. Lack of Adequate Facilities and Design Criteria

A) It is mandatory that all processing and loading buildings be built in accordance with specification of AMCR 385-224 or other applicable manuals. Floor and bench covering should be surface free of cracks and surfaces which are easily cleaned. All floors, benches, and equipment bonded and grounded, explosion proof lighting, switches, fixtures and equipment.

B) Remote Control Handling

It is a must that the screening process and rebowling of lead azide be done by remote control devices. Increment scooping should be done by remote control. There are at least three excellent models designed by Day and Zimmerman and used at Lone Star Ordnance.

C) Shield Design

It is vitally important that shielding of loading operations be designed in accordance with accepted drawing and specification. Shielding designed without approved drawing and specifications must be tested for the quantity intended plus 25 percent for a safety factor. Over the years, I have seen many shields used that are just window dressing. An inadequately designed shield in many cases is worse than none as the shield itself becomes a missile.

3. Lack of Knowledge of the Characteristics of Lead Azide

A) One of the greatest contributing factors in accidents relating to the handling, processing, and loading of lead azide is the apparent lack of knowledge of its characteristics by those who actually do the processing, handling, and loading. I do not mean to say the industry lacks this knowledge, far from it, but I do know that this knowledge is withheld to some degree from those who need it, perhaps from the fear that it drives the employees away if all were told. Over a 30 year period, I have heard it said many times, "What they don't know won't hurt them." I say what they don't know will kill or maim them. It is incumbent on us all to be positive that all employees as well as supervision are made aware of the characteristics of lead azide. This can be accomplished only by intensified training, through demonstration, follow up, and by keeping the S.O.P.s posted at all times in work stations or work areas.

4. The Human Element

A) There is another area that is somewhat neglected, that is in the selection of personnel who are to work with lead azide. This is not always willful neglect, but in many cases due to the labor market or the urgency of starting contracts. Personnel selected to work with lead azide

should be mature, calm, emotionally stable, and be of moderation in their personal habits. Having personnel of that caliber makes it much easier to get them safety oriented. Human errors and failing must be allowed, for all of us at one time have had a bad day, fail to understand, act without thinking, and sometimes become upset over conditions at work or in the home.

The probability of a serious accident may never be reduced to zero but the probability of an adverse accident can be kept very low by the use of automation and remote control handling equipment. The use of such devices, no doubt, will compensate for many human errors. There is yet a long way to go in the industry, as a whole, to fill the gaps where automation and remote control handling devices may be used to reduce the exposure to personnel working with lead azide.

Over a period of approximately 27 years, I have trained crews both male and female in the handling, processing, and loading of dextrinated lead azide, without a major incident. We at the Atlantic Research Corporation, West Hanover, Massachusetts, have had this same excellent experience in the use of dextrinated lead azide. However, we have not been so fortunate with the use of non-dextrinated lead azide.

The incidents of blows with non-dextrinated lead azide in the loading of detonators was much greater than with dextrinated. We had one incident with hand scooping. Hand scooping was stopped at this point and remote automatic scoopers were installed. There was one incident involving the dropping of a flask of mine mix which we tried to reproduce under most severe tests and were unable to reproduce. There was an incident of a foreman placing rejected detonators with non-dextrinated lead azide into water - then an incident of one fatality and eleven major injuries. I am not going into details of these incidents, as this would infringe on another speaker's subjects. We have not developed the confidence in non-dextrinated lead azide as with dextrinated. In fact, we prefer not to use it.

In conclusion, I am going to read a safety poem. I have no idea who wrote it, but it does seem most appropriate.

"Of mistakes and cures, learn the past.
Think and plan, but not too fast.
Something new, take double care.
With our lives, we do not dare.
Instead, we listen, heed the wise.
Minimize, minimize, minimize."

BLANK PAGE

IMPACT SENSITIVITY OF LEAD AZIDE IN DIFFERENT SOLID AND LIQUID MEDIA

by
Louis Avrami and Henry Jackson
Feltman Research Labs, Picatinny Arsenal, Dover, N.J.

ABSTRACT

This work was conducted to determine the effect of different liquids on the sensitivity of lead azide as measured with the Picatinny Arsenal impact machine. The results indicated that different mixtures of lead azide and water, lead azide and Freon TF and lead azide and alcohol-water are more sensitive than dry lead azide when subjected to this sensitivity test.

Also determined was the impact sensitivity of mixtures of lead azide with Cab-O-Sil (COS) and of lead azide with RDX and Cab-O-Sil. Measurements were made of these mixtures in a dry state and wet with Freon TF.

In the dry state the lead azide/RDX/COS mixture is more sensitive than lead azide/COS, which in turn is more sensitive than lead azide. The indications are that when wet with excess Freon the PbN_6/RDX/COS is less sensitive than the dry mixture because most of the "fires" encountered with the wet mixture were weak and low order.

I. INTRODUCTION

Information on the impact sensitivity of lead azide when water wet, alcohol-water wet and Freon wet was required for a munitions application and as a guide in safe-handling the mixtures. The latter information was requested by U.S. Army Procurement and Supply Agency, Joliet, Illinois as a result of an investigation of an accident in an explosives plant handling the compositions.

II. EXPERIMENTAL PROCEDURE

A. Sample Preparation

The preparation of the materials basically followed a uniform procedure: For each series of tests a control batch of lead azide was removed from its shipping container washed and dried in a prescribed method, and then divided into control and test samples.

Most of the lead azide was washed and dried in the following manner: As received, lead azide is immersed in an alcohol solution. Batches weighing 200-250 g were placed in a Buchner funnel with a filter and washed with five portions of 500 ml of 50-50 triple distilled water and 95% ethyl alcohol. Suction was applied for an hour and then the sample was placed in an open oven at 60°C for 24 hours. Finally, the lead azide was placed in a sealed rubber conductive container for use. This was designated Drying Method No. 1.

To simulate the practice followed at the plants Drying Method No. 2 is used as follows: An alcohol-wet batch of stock lead azide was washed in a Buchner funnel with about 2 liters of distilled water. The same amount of absolute ethyl alcohol was then used to wash the sample thoroughly and the sample was rinsed with about one liter of Freon TF. The sample was then placed on filter paper and air dried for about an hour before being stored in a sealed rubber conductive container. When required for testing, the sample was further dried in a vacuum oven at 60°C for 24 hours. Fifteen series of impact tests were run. In all but Series #1 and #11 the lead azide control samples were prepared and dried according to Drying Method No. 1. Series #1 was a dry lead azide batch on hand, but

it is further dried in an open oven at 100°C for 17 hours before use. Series #11 was prepared according to the Drying Method No. 2. The samples of lead azide and Cab-O-Sil and lead azide, RDX, and Cab-O-Sil were received already blended. These mixtures had been blended in the dry state in a NOL mixer with a very slow cycle (13 rpm for about 8 minutes). A sample of the lead azide batch used for these mixtures was made available for controls.

The size of the cavity in the die cup which contains the sample in the impact test machine [Figure 1(a)] dictated the amount of liquid used in the mixtures of lead azide with water, water-alcohol and Freon. Two lead azide and water mixtures were tested, containing respectively 16.7% and 28% by weight of distilled water. The time interval between the preparation of the mixtures, the loading and the testing was kept to a minimum to avoid excessive evaporation.

The same liquid contents were used for the lead azide and alcohol-water mixture. Two types of ethyl alcohol were used: Factory stock and 95%. Due to the volatility of the Freon the specified liquid contents could not be maintained in mixtures of lead azide and Freon and Lead Azide, COS and Freon.

For samples described as "Freon paste" the mixtures were prepared by simply pouring Freon TF on a batch of lead azide in a container so that the level of the Freon rose just above the top surface of the lead azide. When loading the die cups the brass cap was placed over the cups immediately to reduce evaporation to a minimum. Only 6-8 samples were loaded at one time.

For samples described as "excess Freon" a different loading procedure was used. A dry sample was loaded into the die cup and then Freon TF was added by drops from a burette until the die cup was filled. The brass cap was placed over the die cup and assembled in a press. These samples w... loaded and fired as quickly as possible. On an average a sample was loaded and fired in about 30 seconds.

B. Impact Sensitivity Determintion

The Picatinny Arsenal impact sensitivity tester was used to conduct the investigation. The standard operating procedure was followed using both the 2 and 1 kilogram drop weights (Ref. 1).

With the 2 kilogram weight the range in drop heights required to initiate the compositions was small; therefore, the drop weight was reduced to 1 kilogram to widen the range.

Each test was conducted to obtain a curve of percent fire as a function of height. Twenty samples are tested at each height and normally 6-10 heights are selected to obtain the range from fires (F) to no-fires (NF). The minimum interval between different heights was 1 inch.

A new series of tests was started whenever:

a. A new batch or lot of lead azide was used

b. A change in drop weight was employed

c. A new mixture was studied

d. A difference in time intervals between testing control samples and testing the mixtures

e. A different method of washing and drying had been used

f. A different operator performed the tests (4 different operators were used).

In all of the tests conducted efforts were made to maintain the ambient temperature and relative humidity within a small range ($\pm$ 4°F and $\pm$ 3% R.H.).

The impact test machine uses only a very small sample (15-25 mg) and the question arises as to the significance of data obtained with such small quantities when in practice much larger quantities are handled.

In order to obtain some indication of the effect of a scale-up to larger quantities, a modification of the standard impact test was used as shown in Figure 1. The brass cap, which is usually seated over the die cup, was used as a receptacle into which a charge ($\sim$ 25 mg) of lead azide was placed. Freon TF was added in sufficient amounts to be at least 2-3 times the volume of the lead azide. Upon this a die cup was placed with the flat side seated on the Freon. Another die cup in reverse position was placed on top of the first die cup so that the striker or drop-weight would strike on a flat surface. The heights 6" and 9" were arbitrarily selected and twenty shots were tested at each height. A 2 kg drop weight was used.

III. RESULTS

Fifteen series of tests were conducted totaling about 80 tests. Each test consisted of a determination of the number of "fires" or "no fires" for a number of drop heights. In each test a minimum of five and a maximum of 11 drop heights were used, with 8 being the average. The results and purpose of each series are given in Tables I through XV.

In the modified test using the brass cap the results revealed that with a 2 kg drop-weight one of twenty samples tested fired at six inches and three of twenty fired at nine inches.

A visual inspection of the data the trend indicates strongly that according to the impact test method the mixtures of lead azide with Freon TF, water or water-alcohol are more sensitive than the dry lead azide. This was also borne out by plotting the experimental data graphically (Figs 2, 3 and 4). Except for the last series of tests only six in over 75 tests indicated the opposite trend. However two of these (PbN_6 w/Freon (x) compared to PbN_6) showed the opposite effect when excess Freon was used.

Independent investigations by Hanna and Polson (Ref 5) and Brown (Ref 6) confirmed the findings with the mixtures of lead azide and Freon TF.

IV DISCUSSIONS

In an effort to show that the apparent differences between samples as indicated by the raw data were real the data were subjected to statistical analysis. The method of data analysis proposed by Kemmey (Ref 2) was applied to the results. This method combines the χ^2 (chi-squared), or goodness-of-fit test, with the Karber test to provide a means to categorize the materials in terms of relative sensitivity.

The χ^2 test permits a comparison to be made between two materials which have been tested at a number of drop heights. For a chosen level of confidence (in this case 95%) and the number of degrees of freedom corresponding to the number of heights the test permits a statement to be made about the significance of apparent differences in sample behavior.

The test has the advantage that samples may be compared without making any assumptions about the shape of curve or the distribution of % fires vs. drop heights. Furthermore if the drop heights cover a sufficiently wide range, the test is sensitive to changes in that distribution.

Since the χ^2 test does not give any insight into the nature of the distribution or indicate a means of ranking the samples in order of sensitivity, this inadequacy is surmounted with the inclusion of the Karber test. This procedure yields results in the form of an estimated mean height that will cause samples to fire (the mean critical height). This is the height at which a 50% probability of fire occurs. An estimated standard deviation based upon the percentage fires is also obtained at a number of different heights. Assuming that the height distribution is normal (which is contrary to experiment), the values for the mean height and standard deviation specify the performance of the sample on impact testing, and the mean may be used as some measure of the sensitivity, with the standard deviation as some measure of the predictability of impact behavior of the sample (Ref 2). Briefly, when the χ^2 test indicates that materials are significantly different, the Karber method is useful in ordering materials with regards to sensitivity.

Unfortunately complete comparisons between pairs of samples could not be obtained if the measurements had not been made at the same heights. However, under these circumstances an available computer still permitted this statistical analysis since the coding would give the Karber analysis to be performed and also gave a graphical plot of percent firings versus

drop heights. The curves drawn in Figures 2 to 6 are the results of this computer calculated "best fit" to the data points. In most cases where the χ^2 test could not be applied indications of differences in sample behavior were shown on the graphs, and the mean critical height and standard deviation from the Karber analysis indicated the relative order of sensitivity.

At least 60 comparisons of the behavior of samples were made by statistical analysis and the results are summarized in Table XVI.

In presenting the results of the statistical analysis in Table XVI the following notation was used. In the "Comment" column the phrase "More sensitive" or "Less Sensitive" was used when the statistical analysis indicated such. The comparison was always made with the first sample being compared to the second sample - normally a wet sample versus a dry one. If no adequate χ^2 test could be made a judgement as to relative sensitivity was made based upon the plot and the Karber mean critical height. For example, if the graph and the mean critical height indicated that a sample was more sensitive the expression "as sensitive or more" was used. If less sensitive the expression "as sensitive or less" was used. This notation was used especially when the mean and standard deviations of data overlapped.

Also included in this category were at least eight comparisons of data which were"apparently"different. These were examples where the mean critical height and standard deviation of each sample did not overlap but due to the lack oicommon heights the χ^2 test could not be applied.

In all of the testing conducted the addition of the different liquids to lead azide alone sensitized the explosive mixture. When lead azide was mixed with Cab-O-Sil and with RDX and Cab-O-Sil, the results indicated that PbN_6/RDX/COS was the most sensitive dry mixture with Pb/COS next, followed by PbN_6 (Fig 4). When mixed with Freon TF the PbN_6/COS w/Freon was more sensitive than the dry mixture, but the PbN_6/RDX/COS with Freon TF was less sensitive than the dry PbN_6/RDX/COS (Series #15) (Fig 6). Significantly the tests that fired in the COS/Freon mixtures were often very weak or of low order. Although the results show that more "fires" occurred in the lower range for the lead azide/RDX/Cab-O-Sil mixture when immersed in Freon the Karber mean critical height in all the tests indicate that the dry state is more sensitive. This also assumes all the "fires" on an equal basis. The belief is that the "gel" action of the Freon TF plays a large part in this action. This may include a dispersion characteristic or a greater heat dissipation overcoming the heat evolution.

In trying to understand what is going on and why the lead azide is more sensitive in the impact test with the liquids indicated, a brief description of the mechanics of the test is now given.

Under the action of a falling weight which is represented by kinetic energy, the striker overcoming the resistance of the deformed brass cap and charge exerts a dynamic pressure on the explosive. This is characterized by a sudden increase in specific pressure and then an almost equal decrease.

As a rule it is commonly believed that the initiation of an explosion by impact results from the formation of a critically-sized

hot spot in the confined material. The heating can be caused by any or all of the following (Ref 3):

a. Adiabatic compression of air pockets

b. Friction between small crystals of explosives of other ingredients of a mixture

c. High strain rates of a viscous or plastic nature

d. Interaction of weak shock waves

e. Internal friction

Liquids are generally incompressible; thus a possible rationalization of the observations is that in the confined situation represented by the die cup the presence of the liquid aided in the efficient transfer of shock when the samples were subjected to impact. The experimental confined conditions may, however, not be significantly different from other conditions of confinement likely to be encountered in shipping and handling lead azide, e.g. a unit volume of lead azide may be considered to be "confined" by the other lead azide in a large shipping container. In the same vein it must be berne in mind that "fires" were obtained in the modified test which still included confinement but of reduced nature in comparison with the standard test. What has to be ascertained further is whether any "fires" can be obtained in an unconfined condition. What can be defined as "unconfined" is an area of future study.

Another factor to be considered which may account for the increased sensitivity of wet lead azide is the inclusion of air in the form of minute bubbles. Adiabatic compression of bubbles is known or believed to sensitize liquid explosives.

One of the most important reasons for impact testing is to establish whether the explosive tested constitutes an impact hazard to personnel or operations. It is a simple and r d means for ranking materials according to explosion hazard, but it is only one measure of several that are used to characterize sensitivity. The only reliable technique of establishing such a hazard is to express sensitivity data as the threshold of ignitiability and to compare this with operating conditions which can be expressed as potential energy.

CONCLUSIONS

Based upon the procedure for the impact testing that was followed the following general statement can be made:

According to the Picatinny Arsenal impact sensitivity test mixtures of lead azide with Freon TF, water or water-alcohol are more sensitive than a dry sample of lead azide. The combination of the χ^2 and Karber test provided the statistical analysis to confirm the results.

The following observations are also made:

a. The most sensitive of the mixtures tested is the lead azide with excess Freon TF.

b. Comparisons were more readily discernible with those samples that had more liquids in the mixtures; i.e., excess Freon, 28% H_2O and 28% H_2O-alcohol.

c. With the dry and wet mixtures the following trends were noted:

(1) PbN_6/COS (80/5) was more sensitive than PbN_6.

(2) PbN_6/COS w/Freon was more sensitive than PbN_6.

(3) PbN_6/COS w/Freon was more sensitive than PbN_6/COS ("fires" were mostly weak).

(4) PbN_6/RDX/COS (30/40/4.2) was as or more sensitive than PbN_6/COS.

(5) PbN_6/RDX/COS w/Freon was less sensitive than PbN_6/RDX/COS. ("Fires" were very weak or low order.)

d. For the most part the different batches of lead azide, changes in drop weight, different methods of preparation, time difference in testing on different operations had no effect on the relative order of sensitivity (Figs 2 and 3). No efforts have been made regarding the variations in the $E_{.50}$ values for the dry lead azide samples from lot to lot. It is to be noted that in the same lots the increase in the $E_{.50}$ value for the control samples seem to be increasing as a function of time.

e. Under specific conditions with proper confinement a scale-up of the impact test as shown in the modified test can produce "fires".

ACKNOWLEDGEMENTS

Part of this work was funded by the Ammunition Engineering Directorate for Project Gravel.

Acknowledgements are given to E. Dalrymple, N. Palmer and L. Hayes for performing the impact sensitivity test. The assistance of Dr. Peter J. Kemmey with the statistical analyses is gratefully acknowledged. The constructive criticisms of this report by Dr. R.F. Walker are deeply appreciated.

REFERENCES

1. Clear, A.J. "Standard Laboratory Procedures for Determining Sensitivity, Brisance and Stability of Explosives", PATR 3278, December 5, 1965.

2. Kemmey, P.J. "Analysis of the Sensitivity to Initiation to Impact, Various Statistical Methods", PATR 1812, April 1968, in publication.

3. Bowden, F.P. and Yoffe, A.D. "Initiation and Growth of Explosives in Liquids and Solids" Cambridge University Press (1952).

4. Siele, V.I., Bronner, H and Jackson, H.J., "Impact Sensitivity of Lead Azide, RDX, Cab-O-Sil (Gravel) System: Effect of Temperature, Freons and Water on Sensitivity (U) PATR 3671, March 1968 (C).

5. Hanna, H.A. and Polson, J.R. "Investigation of Static Electrical Phenomena in Lead Azide Handling", Mason and Hanger-Sila Mason Co, Inc., Tech Report No. 98-A, 11 December 1967.

6. Brown, J.A. "Sensitivity Studies for Project Gravel" Monthly Progress Reports No. 2-6, July 1967 - January 1968 , Contract DAAA21-67-C-1108(U).

TABLE I

SERIES #1

2 Kilogram Drop-Weight

Height (inches)	PbN_6 Control F	PbN_6 Control NF	PbN_6 w/28% H_2O F	PbN_6 w/28% H_2O NF	PbN_6 w/16.7% H_2O F	PbN_6 w/16.7% H_2O NF	PbN_6 Control F	PbN_6 Control NF
1	-	-	4	16	-	-		
2	0	20	10	10	1	19		
3	3	17	16	4	1	19	0	20
4	11	9	16	4	3	17		
5	9	11	17	3	4	16		
6	9	11	18	2	8	12	9	11
7	12	8	19	1	8	12		
8	14	6	20	0	6	14		
9	18	2			12	8	8	12
10	18	2			11	9		
11	17	3			13	7		
12					12	8	11	9
13					12	8		
14								
15							13	7
16							19	1
17								
18					17	3	15	5
19								
20							17	3
21								
22								
23								
24								
25							20	0
26							20	0
27								
28								
29								
30								
$E_{.50}$	5.20 ± 2.264		2.40 ± 2.043		7.77 ± 5.224		14.70 ± 4.458	
Test No.	#1		#2		#3		#4	
Date Tested	5/12/67		5/12/67		5/13/67		5/13/67	

NOTES: 20 Tests/Height   Lead Azide Dried 17 Hours at 100°C.
Tests 1 and 2 caps pressed down by hand.
Tests 3 and 4 caps pressed down by press.

TABLE II

SERIES #2

2 KG Drop Weight

Height Inches	PbN_6 Control F	PbN_6 Control NF	PbN_6 w/16.7% H_2O F	PbN_6 w/16.7% H_2O NF	PbN_6 w/28% H_2O F	PbN_6 w/28% H_2O NF	PbN_6 Control F	PbN_6 Control NF	PbN_6 w/Freon (x) F	PbN_6 w/Freon (x) NF	PbN_6 w/Freon (xx) F	PbN_6 w/Freon (xx) NF
1			0	20							2	18
2	0	20	1	19	8	12			0	20	12	8
3	1	19	4	16	5	15	0	20	8	12	16	4
4												
5												
6	5	15	16	4	16	4	4	16	17	3	20	0
7	7	13										
8												
9	13	7	19	1	18	2	10	10	9	11	20	0
10			19	1								
11												
12	15	5	19	1	20	0	14	6	18	2	20	0
13												
14	20	0										
15	20	0	20	0			16	4	20	0	20	0
16												
17												
18	19	1					20	0	20	0		
19												
20												
21			20	0			19	1	20	0		
22												
23												
24							18	2				
25												
26												
27	20	0					20	0				
28												
29												
30												
E_{50}	8.37 ± 3.241		4.95 ± 2.373		3.60 ± 3.367		11.17 ± 4.743		4.90 ± 3.295		2.15 ± 1.263	
Test No.	#7		#20		#90		#9		#102		#103	
Date Tested	5/15		5/17		5/26		5/16		5/29		5/29	
Room Temp	72°F		71°F		71°F		72°F		72°F		72°F	
Rel. Hum.	51%		56%		51%		55%		58%		53%	

NOTES: Drying Method #1
(x) A paste made from PbN_6 and Freon TF
(xx) Extra drops added to die cup and paste

TABLE III

SERIES #3

1 Kg Drop Weight

Height Inches	PbN_6 Control F	NF	PbN_6 w/Freon (x) F	NF	PbN_6 w/Freon (xx) F	NF	PbN_6 Control F	NF	PbN_6 w/Freon (x) F	NF	PbN_6 w/Freon (xx) F	NF
1												
2											7	13
3	0	20	0	20	8	12	2	18	0	20	12	8
4	1	19	4	16	12	8	4	16	0	20	15	5
5												
6	5	15	4	16	12	8	10	10	5	15	20	0
7	12	8	4	16	16	4	12	8	2	18	19	1
8	12	8	5	15	14	6	17	3	5	15	20	0
9												
10	18	2	14	6	18	2	13	7	6	14	18	2
11												
12												
13												
14												
15												
16	19	1	15	5	20	0	20	0	10	10	20	0
17												
18	20	0	17	3					17	3		
19												
20	20	0	19	1					18	2		
21												
22												
23												
24	20	0	20	0					20	0		
25												
26												
27												
H_{50}	7.45 + 2.476		10.47 + 5.402		4.20 + 4.230		6.37 + 3.027		14.75 + 2.296		2.40 + 1.943	
Test No.	#126		#127		#128		#131		#132		#133	
Date	6/1		6/1		6/1		6/2		6/2		6/2	
Temp.	74°F		74°F		75°F		75°F		75°F		75°F	
R.H.	53%		52%		52%		54%		54%		54%	

NOTES: PbN_6 was RD 1333 (3895) from Dr. F.B. Wells, P.A. Dry sample furnished.

TABLE IV

SERIES #4

2 Kg Drop Weight

Height Inches	PbN_6 Control F	PbN_6 Control NF	PbN_6 w/16.7% H_2O F	PbN_6 w/16.7% H_2O NF	PbN_6 w/20% H_2O F	PbN_6 w/20% H_2O NF
1	0	20				
2	0	20	0	20	0	20
3	2	18	4	16	6	14
4	7	13				
5	14	6				
6	17	3	6	14	10	10
7	18	2				
8	17	3				
9	19	1	15	5	15	5
10	20	0	17	3	13	7
11						
12			20	0	20	0
13						
14						
15						
16						
17						
18						
19						
20						
E_{50}	4.75 ± 1.704		6.92 ± 2.705		6.27 ± 3.227	
Test No.	#217		#216		#215	
Date	7/27		7/26		7/26	
Temp.	76°F		73°F		73°F	
R.H.	55%		55%		55%	

NOTE: Lead Azide Lot 53-11

TABLE V

SERIES #5

Height Inches	2 Kg PbN6 Control F	NF	2 Kg PbN6 w/16.7% H_2O F	NF	2 Kg PbN6 w/28% H_2O F	NF	2 Kg PbN6 w/Freon (x) F	NF	1 Kg PbN6 w/Freon (x) F	NF	1 Kg PbN6 w/Alc-H_2O* F	NF	1 Kg PbN6 w/Alc-H_2O* F	NF
1	0	20	0	20	0	20								
2	2	18	7	13	5	15							0	20
3	8	12	10	10	16	4					0	20	1	19
4	10	10	13	7	16	4								
5	18	2	19	1	16	4	0	20	0	20				
6	20	0	20	0	18	2			2	18	2	18	11	9
7	20	0							6	14				
8					18	2			5	15				
9	20	0					2	18	8	12	4	16	14	6
10			19	1			8	12	9	11				
11														
12					20	0	16	4	15	5	10	10	14	6
13														
14									14	6				
15							19	1			16	4	20	0
16														
17														
18							19	1	20	0	20	0		
19														
20														
H50	(est) 3.60±1.166		3.05±1.328		3.30±2.434		9.97±2.794							
Test	#149		#329		#317		#320		#377		#376		#378	
Date	6/7		8/29		8/25		8/26		9/20		9/20		9/21	
Temp.	72°F		72°F		74°F		70°F		68°F		68°F		70°F	
R.H.	55%		55%		56%		56%		56%		56%		55%	

NOTES: Lead Azide Lot 51-18
(x) Paste made with PbN6 and Freon
*50% Factory stock alcohol - 50% Distilled water.

TABLE VI

SERIES #6

1 Kg Drop Weight

Height Inches	PbN_6 Control F	NF	PbN_6 w/16.7% H_2O F	NF	PbN_6 w/28% H_2O F	NF	PbN_6 w/Freon (x) F	NF	PbN_6 w/Freon (xx) F	NF	PbN_6 w/Freon (xx) F	NF
1												
2									0	20	0	20
3	0	20	1	19					0	20	7	13
4			2	18	0	20	0	20	1	19	9	11
5											10	10
6	1	19	3	17	5	15	1	19	3	17	15	5
7			9	11			1	19	6	14	17	3
8			11	9					11	9	14	6
9	1	19			6	14			12	8	15	5
10			14	6	6	14	1	19			17	3
11												
12	5	15			18	2					20	0
13												
14												
15												
16			6	14	18	2	10	10	17	3		
17												
18	8	12	11	9	16	4	12	8	19	1		
19												
20					19	1	11	9				
21												
22												
23												
24	13	7	19	1			18	2				
25												
26												
27	16	4										
28												
29												
30	19	1										
36	20	0										
E_{50}	19.65+7.568				9.17+3.898		14.40+6.499		8.77+4.118		6.55+2.205	
Test	#404		#356		#351		#355		#360		#405	
Date	10/11		9/12		9/11		9/12		9/13		10/11	
Temp	77°F		72°F		72°F		73°F		73°F		77°F	
R.H.	54%		56%		56%		57%		57%		53%	

NOTES: Lead Azide Lot 53-11. (x) Freon Paste, (xx) Excess Freon.

TABLE VII

SERIES #7

1 Kg. Drop Weight

Height Inches	(26B) PbN6 Control P	NP	PbN6 w/16.7% H_2O P	NP	(27B) PbN6 Control P	NP	PbN6 w/28% H_2O P	NP	(28B) PbN6 Control P	NP	PbN6 w/28% Alc-H_2O P	NP	(29B) PbN6 Control P	NP	PbN6 w/Freon (x) P	NP	PbN6 w/Freon (xx) P	NP
1																	1	19
2											0	20					4	16
3			0	20			0	20			1	19			0	20	6	14
4															2	18	8	12
5			1	19							6	14			6	14	10	10
6	0	20	3	17	0	20	2	18	0	20	8	12	0	20	6	14	15	5
7															7	13	15	5
8													0	20			18	2
9	1	19	11	9	1	19	5	15	1	19	11	9			10	10	18	2
10			11	9	3	17	9	11					2	18	11	9	17	3
11									5	15	16	4			13	7		
12	1	19	15	5	4	16	9	11	5	15			5	15	18	2	20	0
13					5	15	14	6	8	12								
14					8	12			9	11			14	6				
15	4	16	17	3	14	6	18	2	14	6	17	3			20	0		
16	8	12	17	3					16	4			14	6				
17	11	9	19	1					17	3								
18	14	6	20.	0	17	3	19	1	20	0	20	0	15	5				
19																		
20													19	1				
21	14	6			19	1	20	0	20	0								
22	18	2											19	1				
23																		
24	20	0			20	0							20	0				
25																		
26																		
27																		
$E_{.50}$	17.20±3.774		9.82±3.779		14.42±3.446		11.20±3.087		13.55±2.780		8.42±4.314		14.20±3.664		8.52±3.309		4.87±2.906	
Test	#379		#380		#381		#382		#383		#384		#385		#386		#387	
Date	9/26		9/26		9/27		9/27		9/28		9/28		9/29		9/29		9/30	
Temp	73°F		72°F		70°F		76°F		69°F		69°F		71°F		71°F		74°F	
R.H.	54%		55%		55%		55%		57%		56%		56%		58%		57%	

NOTES: 1. Alcohol-H_2O solution consisted of 50-50 95% ethyl alcohol and distilled water.
2. Control tests for each mixture.

TABLE VIII

SERIES #8

1 Kg Drop Weight

Height Inches	PbN_6 Control F	PbN_6 Control NF	PbN_6 w/Freon (x) F	PbN_6 w/Freon (x) NF	PbN_6 w/Freon (xx) F	PbN_6 w/Freon (xx) NF
1						
2			1	19	1	19
3			5	15	7	13
4			6	14	5	15
5					6	14
6	0	20	8	12	14	6
7			11	9	15	5
8			16	4	12	8
9	4	16	19	1		
10			19	1	18	2
11						
12	3	17	18	2	19	1
13						
14						
15	9	11	20	0	19	1
16						
17						
18	7	13				
19	13	7				
20	15	5				
21						
22	13	7				
23						
24	18	2				
25						
26						
27						
28						
29						
30	20	0				
E_{50}	16.67 ± 6.064		5.97 ± 2.979		6.27 ± 3.141	
Test	#398		#399		#400	
Date	10/9		10/9		10/9	
Temp	71°F		70°F		69°F	
R.H.	55%		55%		55%	

NOTES: Lead Azide Lot 51-11
(x) Freon Paste
(xx) Excess Freon

TABLE IX

SERIES #9

1 Kg Drop Weight

Height Inches	PbN_6 Control F	NF	PbN_6 w/16.7% Alc-H_2O F	NF	PbN_6 w/28% Alc-H_2O F	NF	PbN_6 Control F	NF	PbN_6 w/Freon (xx) F	NF
1										
2					1	19			0	20
3							0	20	7	13
4			0	20	1	19			9	11
5									10	10
6	0	20	5	15	6	14	1	19	15	5
7					12	8			17	3
8			3	17	10	10			14	6
9	1	19					1	19	15	5
10			4	16	12	8				
11										
12	4	16	14	6	15	5	5	15	20	0
13					13	7				
14			15	5	12	8				
15	6	14								
16			10	10	20	0				
17										
18	9	11	11	9			8	12		
19										
20										
21	14	6					10	10		
22	14	6								
23										
24	19	1	17	3			13	7		
25										
26										
27	20	0					16	4		
28										
29										
30			20	0			19	1		
36							20	0		
E.50	17.67±5.019				11.20±1.475		19.65±7.568		6.55±2.205	
Test	#401		#402		#403		#404		#405	
Date	10/10		10/10		10/10		10/11		10/11	
Temp.	71°F		70°F		74°F		77°F		77°F	
R.H.	55%		55%		57%		54%		53%	

NOTES: Lead Azide Lot 53-11
Alcohol is factory stock ethyl alcohol.

TABLE X

SERIES #10
1 Kg Drop Weight

Height Inches	PbN_6 Control F	NF	PbN_6 w/28% H_2O F	NF	PbN_6 w/Freon (xx) F	NF	PbN_6 w/28% Alc H_2O F	NF
1								
2					0	20		
3							0	20
4					5	15	8	12
5								
6					14	6	5	15
7							14	6
8					18	2		
9							10	10
10					18	2		
11								
12	0	20	3	17	18	2	11	9
13							19	1
14								
15	3	17	7	13	20	0	16	4
16							20	0
17								
18	7	13	9	11			20	0
19								
20								
21	2	18	13	7				
22								
23								
24	11	9	13	7				
25								
26								
27								
28								
29								
30	13	7	18	2				
36	20	0	20	0				
E_{50}	$24,07 \pm 7.465$		18.30 ± 9.724		5.75 ± 2.844		9.75 ± 2.177	
Test	#407		#408		#406		#409	
Date	10/12		10/12		10/12		10/13	
Temp	77°F		77°F		76°F		72°F	
R.H.	53%		55%		54%		55%	

NOTES:
1. New Lot from Flare Northern - no lot number - after washing dried 24 hours @ 60°C in open oven.
2. Alochol - Factory stock ethyl alochol.

TABLE XI

SERIES #11

1 Kg Drop Weight

Height Inches	PbN_6 Control F	PbN_6 Control NF	PbN_6 w/20% H_2O F	PbN_6 w/20% H_2O NF	PbN_6 w/Freon (xx) F	PbN_6 w/Freon (xx) NF
1						
2					0	20
3			0	20	5	15
4					4	16
5					5	15
6	1	19	1	19	15	5
7					17	3
8					16	4
9	3	17	3	17	20	0
10			0	20		
11						
12	5	15	2	18		
13						
14						
15	8	12	10	10		
16						
17						
18	8	12	14	6		
19						
20						
21	17	3	15	5		
22						
23						
24	17	3	17	3		
25						
26						
27	15	5	20	0		
28						
29						
30	17	3				
36	19	1				
E_{50}	19.42 + 7.439		-		5.57 + 1.447	
Test	#410		#411		#412	
Date	10/14		10/14		10/14	
Temp	73°F		74°F		75°F	
R.H.	54%		54%		54%	

NOTES: Same lead azide as series #10 but washed differently and dried in vacuum oven for 24 hours at 60°C (Drying Method #2).

TABLE XII

SERIES #12

1 KG Drop Weight

Height Inches	PbN_6 F	PbN_6 NF	PbN_6 w/Freon F	PbN_6 w/Freon NF	PbN_6 F	PbN_6 NF	PbN_6/Freon F	PbN_6/Freon NF	PbN_6 F	PbN_6 NF	PbN_6/Freon F	PbN_6/Freon NF
1											0	20
2			0	20			0	20			2	18
3			1	19			2	18				
4	0	20	4	16			9	11			16	4
5	2	18	12	8			7	13				
6	6	14	11	9	0	20	13	7	0	20	17	3
7			15	5	3	17						
8	7	13	17	3			17	3				
9					6	14	18	2				
10	13	7	19	1			17	3			20	0
11							20	0				
12	16	4	20	0	7	13			2	18	18	2
13												
14					19	1						
15	20	0			17	3			7	13	20	0
16												
17												
18					20	0			8	12		
19												
20												
21									17	3		
22												
23												
24									19	1		
25												
26												
27												
28												
29												
30									19	1		
31												
32												
33												
34												
35												
36									20	0		
E_{50}	8.95+2.997		5.62+2.145		11.32+2.805		5.45+2.359		17.77+5.140		5.35+3.930	
Test No.	1001		1002		1003		1004		1005		1006	
Date	1/31/68		1/31/68		2/5		2/5		2/10		2/10	
Temp	72°F		72°F		73°F		76°F		77°F		75°F	
R.H.	55%		55%		55%		57%		55%		55%	

NOTES: Lead Azide Batch JA-4-62

TABLE XIII

SERIES #13

1 Kg Drop Weight

Height Inches	PbN_6 F	PbN_6 NF	PbN_6/COS F	PbN_6/COS NF	PbN_6/COS/Freon F	PbN_6/COS/Freon NF	PbN_6/COS F	PbN_6/COS NF	PbN_6/COS/Freon F	PbN_6/COS/Freon NF	PbN_6/COS F	PbN_6/COS NF	PbN_6/COS/Freon F	PbN_6/COS/Freon NF	PbN_6/COS F	PbN_6/COS NF	PbN_6/COS/Freon F	PbN_6/COS/Freon NF
1					(1)4	16			0	20			1	19			3	17
2					(2)18	2			(8)15	5	0	20	3	17			13	7
3			0	20			0	20	(7)11	9	1	19						
4			0	20	(4)18	2	4	16	(8)10	10	3	17	5	15	0	20	14	6
5	0	20	3	17			14	6	(4)8	12	9	11						
6	1	19	10	10	(6)16	4	17	3	(2)9	11	17	3	8	12	2	18	15	4
7	2	18	17	3			20	0			20	0			5	15		
8					(1)16	4			(2)9	11			11	9	11	9		
9	6	14	20	0					(5)16	4								
10					(2)16	4			(5)17	3			14	6	17	3	19	1
11																		
12	13	7			(1)18	2							19	1	20	0	17	3
13	12	8																
14	18	2																
15	19	1			19	1							18	2			20	0
16	20	0																
17																		
18					20	0							20	0				
19																		
E_{50}	10.75±2.678		6.07±.993		3.65±4.787		4.65±8.63		4.92±3.095		5.00±.983		7.17±4.055		9.07±1.654		3.27±3.425	
Date	1/29		1/29		1/29		2/3		2/3		2/5		2/6		2/10		2/10	
Test	1007		1008		1009		1010		1011		1012		1013		1014		1015	
Temp.	76°F		76°F		75°F		74°F		74°F		74°F		74°F		74°F		74°F	
R.H.	56%		56%		55%		56%		55%		55%		54%		56%		53%	

NOTES: 1. Lead Azide Batch JA-4-62. 2. Mixture of Lead Azide/COS is 80/5.

3. ( ) - Number in parenthesis indicates number of low order detonation (weak).

4. Mixtures blended dry (NOL Method) - Prepared 10-31-67

TABLE XIV

SERIES #14

1 Kg Drop Weight

Height Inches	PbN6/COS F	PbN6/COS NF	PbN6/COS/FREON F	PbN6/COS/FREON NF	PbN6/COS F	PbN6/COS NF	PbN6/COS/Freon F	PbN6/COS/Freon NF
1			2	18			1	19
2			3	17			4	16
3			16	4				
4	0	20			0	20	12	8
5	2	18						
6	3	17	11	9	5	15	17	3
7	5	15			9	11		
8					11	9	10	10
9	15	5	15	5	17	3		
10	19	1			19	1	18	2
11	20	0						
12			16	4	20	0	19	1
13								
14								
15			20	0			20	0
$E_{.50}$	7.80±1.509		7.03±4.294		7.35±1.701		4.35±3.190	
Date	2/16		2/16		2/17		2/17	
Test	1022		1023		1024		1025	
Temp	71°F		74°F		72°F		70°F	
R.H.	55%		55%		55%		54%	

NOTES: Everything same as Series #13 just 10 days later and different operators Lead Azide Lot JA-4-62.

TABLE XV

SERIES #15

1 Kg Drop Weight

Height	PbN_6/RDX/COS F	PbN_6/RDX/COS NF	PbN_6/RDX/COS/Freon F	PbN_6/RDX/COS/Freon NF	PbN_6/RDX/COS F	PbN_6/RDX/COS NF	PbN_6/RDX/COS/Freon F	PbN_6/RDX/COS/Freon NF	PbN_6/RDX/COS F	PbN_6/RDX/COS NF	PbN_6/RDX/COS/Freon F	PbN_6/RDX/COS/Freon NF
1			(1)3	17	0	20	0	20	0	20	(3)6	14
2	0	20	(1)11	9	3	17	(2)4	16	4	16	(5)7	13
3	3	17			6	14	(3)10	10	13	7	(5)12	8
4	8	12	(4)15	5	12	8	(15)17	3	20	0	(4)9	11
5	16	4			19	1	(5)10	10				
6	18	2	(4)16	4	20	0	(6)11	9	20	0	(9)12	8
7	20	0										
8							(6)11	9				
9									20	0	(3)10	10
10			(1)12	8			(6)10	10				
111												
12									20	0		
13												
14												
15							(9)18	2				
16												
17												
18			(2)18	2			(11)20	0			(9)20	0
19												
20												
21												
22												
23												
24			20	0								
25												
$E_{.50}$	4.25±1.097		4.95±6.496		3.50±1.103		6.65±6.678		2.65±.665		7.82±5.563	
Date	1/29		1/29		2/3		2/3		2/6		2/6	
Test No	1016		1017		1018		1019		1020		1021	
T°F	71°F		76°F		72°F		72°F		73°F		74°F	
R/H	57%		55%		56%		55%		54%		53%	

NOTES: Lead Azide lot JA-4-62, mixtures dry blended (NOL Method) same as Series #13
( ) indicates number of weak detonations. Mixture rates of PbN_6/RDX/COS is 30/40/4.2.

TABLE XVI

Results of Statistical Analysis of Impact Tests Using Chi-Square Goodness of Fit (95% Confidence Level) and Kerber Methods

Test No.	Sample	Drop Weight (kg)	Chi-Square Are Samples Statistically Different	Is Difference Shown by Graph?	Kerber Mean Critical Ht ($\bar{x}_{50}$)	σ	Comments
2	PbN_6 w/28% H_2O	2	Yes	Yes	2.40	2.043	More Sensitive
1	PbN_6	2			5.20	2.264	
90	PbN_6 w/28% H_2O	2	*	Yes	3.60	3.367	As Sensitive
7	PbN_6	2			8.37	3.241	
215	PbN_6 w/28% H_2O	2	*	Yes	6.27	3.227	As Sensitive or Less
217	PbN_6	2			4.75	1.704	
317	PbN_6 w/28% H_2O	2	*	Same	3.30	2.438	Same
149	PbN_6	2			3.60	1.186	
382	PbN_6 w/28% H_2O	1	Yes	Yes	11.20	3.087	More Sensitive
381	PbN_6	1			14.42	3.446	
408	PbN_6 w/28% H_2O	1	Yes	Yes	18.30	9.724	More Sensitive
407	PbN_6				24.07	7.465	
411	PbN_6 w/28% H_2O	1	No (Same)	No (Same)	15.00	2.252	As Sensitive
410	PbN_6	1			19.42	7.391	
351	PbN_6 w/28% H_2O	1	*	Yes	9.17	3.898	As Sensitive or More
404	PbN_6	1			19.65	7.568	
20	PbN_6 w/16.7% H_2O	2	*	Yes	4.95	2.373	As Sensitive or More
7	PbN_6	2			8.37	3.241	

TABLE XVI (cont)

3	PbN_6 w/16.7% H_2O	2	•	Same	7.77	5.244	As Sensitive
4	PbN_6	2			14.70	4.458	
216	PbN_6 w/16.7% H_2O	2	•	Yes	6.32	2.705	Less Sensitive
217	PbN_6	2			4.75	1.704	
329	PbN_6 w/16.7% H_2O	2	•	Same	3.05	1.328	As Sensitive
149	PbN_6	2			3.60	1.186	
380	PbN_6 w/16.7% H_2O	1	Yes	Yes	9.82	3.779	More Sensitive
379	PbN_6	1			17.20	3.774	
356	PbN_6 w/16.7% H_2O	1	•	Yes	7.50	.763	As Sensitive
404	PbN_6	1			19.65	7.568	or More
403	PbN_6 w/28% Acl-H_2O	1	•	Yes	11.20	1.475	As Sensitive
401	PbN_6	1			17.67	5.019	or More
409	PbN_6 w/28% Alc-H_2O	1	Yes	Yes	9.75	2.177	More Sensitive
407	PbN_6	1			24.07	7.465	
384	PbN_6 w/16.7% Alc-H_2O	1	•	Yes	8.42	4.314	As Sensitive
383	PbN_6	1			13.55	2.780	or More
402	PbN_6 w/16.7% Alc-H_2O	1	•	Same	-	-	As Sensitive
401	PbN_6	1			17.67	5.019	
103	PbN_6 w/Freon (xx)	2	Yes	Yes	2.15	1.263	More Sensitive
9	PbN_6	2			11.17	4.743	
128	PbN_6 w/Freon (xx)	1	Yes	Yes	4.20	4.230	More Sensitive
126	PbN_6	1			7.65	2.951	
133	PbN_6 w/Freon (xx)	1	Yes	Yes	2.40	1.943	More Sensitive
131	PbN_6	1			6.32	3.431	
360	PbN_6 w/Freon (xx)	1	•	Yes	8.77	4.118	As Sensitive
404	PbN_6	1			19.65	7.568	or More

2

TABLE XVI(cont)

(405 (404	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	*	Yes	6.95 17.65	2.205 7.588	As Sensitive or More
(387 (385	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	Yes	Yes	4.87 14.20	2.906 3.664	More Sensitive
(400 (398	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	Yes	Yes	6.27 16.67	3.181 6.064	More Sensitive
(405 (401	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	Yes	Yes	6.55 17.67	2.205 5.019	More Sensitive
(406 (407	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	Yes	Yes	5.75 24.07	2.844 7.485	More Sensitive
(412 (410	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	Yes	Yes	5.57 19.45	1.447 7.381	More Sensitive
(1002 (1001	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	Yes	Yes	5.62 8.95	2.185 2.997	More Sensitive
(1004 (1003	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	Yes	Yes	5.45 11.32	2.359 2.805	More Sensitive
(1006 (1005	PbN$_6$ w/Freon (xx) PbN$_6$	1 1	Yes	Yes	5.35 17.77	3.930 5.140	More Sensitive
(355 (404	PbN$_6$ w/Freon (x) PbN$_6$	1 1	*	Same	14.40 19.65	6.499 7.568	As Sensitive
(386 (385	PbN$_6$ w/Freon (x) PbN$_6$	1 1	*	Yes	8.59 18.20	3.300 3.664	As Sensitive or More
(397 (398	PbN$_6$ w/Freon (x) PbN$_6$	1 1	Yes	Yes	5.97 16.67	2.979 6.064	More Sensitive
(102 (9	PbN$_6$ w/Freon (x) PbN$_6$	2 2	*	Yes	4.90 11.17	3.295 4.783	As Sensitive or More

TABLE XVI(cont)

127	PbN_6 w/Freon (x)	1	Yes	Yes	10.47	5.402	Less Sensitive
126	PbN_6	1			7.45	2.476	
132	PbN_6 w/Freon (x)	1	Yes	Yes	14.75	2.296	Less Sensitive
131	PbN_6	1			6.57	3.027	
320	PbN_6 w/Freon (x)	2	*	Yes	9.97	2.794	As Sensitive
149	PbN_6	2			3.60	1.186	or Less
1008	PbN_6/COS	1	Yes	Yes	6.07	.993	More Sensitive
1007	PbN_6	1			10.75	2.678	
1010	PbN_6/COS	1	*	Yes	4.65	.863	As Sensitive
1001	PbN_6	1			8.95	2.997	or More
1012	PbN_6/COS	1	*	Yes	5.00	.983	As Sensitive
1001	PbN_6	1			8.95	2.997	or More
1018	PbN_6/COS	1	*	Same	8.07	1.654	As Sensitive
1001	PbN_6	1			8.95	2.997	or More
1022	PbN_6/COS	1	*	Same	7.80	1.509	As Sensitive
1001	PbN_6	1			8.95	2.997	or More
1024	PbN_6/COS	1	*	Same	7.35	1.701	As Sensitive
1001	PbN_6	1			8.95	2.997	or More
1009	PbN_6/COS w/Freon	1	*	Yes	3.65	4.787	As Sensitive
1007	PbN_6	1			10.75	2.678	or More
1011	PbN_6/COS w/Freon	1	Yes	Yes	4.92	3.093	More Sensitive
1001	PbN_6	1			8.95	2.997	
1013	PbN_6/COS w/Freon	1	*	Same	7.17	4.055	As Sensitive
1001	PbN_6	1			8.95	2.997	or Less
1015	PbN_6/COS w/Freon	1	Yes	Yes	3.27	3.425	More Sensitive
1001	PbN_6	1			8.75	2.997	

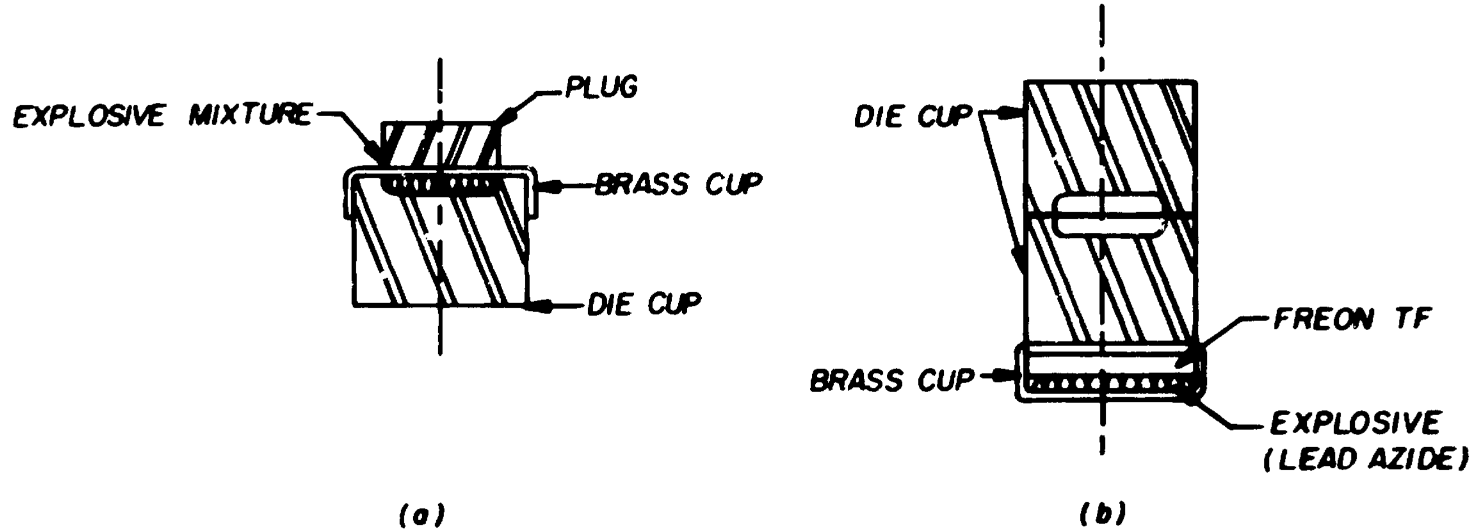
TABLE XVI(cont)

1009	PbN_6/COS w/Freon	1	*	?	3.65	4.787	About Same
1008	PbN_6/COS	1			6.07	.993	
1011	PbN_6/COS w/Freon	1	Yes	Yes	4.92	3.095	Less or
1010	PbN_6/COS	1			4.75	.897	As Sensitive
1013	PbN_6/COS w/Freon	1	*	Yes	7.15	4.055	Less or
1012	PbN_6/COS	1			5.00	.983	as Sensitive
1015	PbN_6/COS w/Freon	1	*	Yes	3.27	3.425	As Sensitive
1014	PbN_6/COS	1			8.07	1.654	or More
1023	PbN_6/COS w/Freon	1	*	Yes	7.02	4.294	As Sensitive
1022	PbN_6/COS	1			7.80	2.987	
1025	PbN_6/COS w/Freon	1	*	Yes	4.35	3.190	As Sensitive
1024	PbN_6/COS	1			7.35	1.701	or More
1016	PbN_6/RDX/COS	1	*	Yes	4.25	1.097	As Sensitive
1008	PbN_6/COS	1			6.07	.993	or More
1018	PbN_6/RDX/COS	1	*	Yes	3.50	1.103	As Sensitive
1010	PbN_6/COS	1			4.75	.897	or More
1020	PbN_6/RDX/COS	1	*	Yes	2.65	.606	More Sensitive
1012	PbN_6/COS	1			5.00	.983	
1017	PbN_6/RDX/COS w/Freon	1	*	Same	4.95	6.496	As Sensitive
1016	PbN_6/RDX/COS	1			4.25	1.097	or Less
1019	PbN_6/RDX/COS w/Freon	1	*	Yes	6.65	6.678	As Sensitive
1018	PbN_6/RDX/COS	1			3.50	1.103	or Less
1021	PbN_6/RDX/COS w/Freon	1	Yes	Yes	7.82	5.563	Less Sensitive
1020	PbN_6/RDX/COS	1			2.65	.666	

*The distribution of results due to lack of common heights is such that no adequate test can be made.

FIGURE I

SIDE VIEW OF STANDARD AND MODIFIED IMPACT TEST FIXTURES



STANDARD P.A. IMPACT TEST FIXTURE

MODIFIED TEST FIXTURE

NOTE: NOT TO SCALE

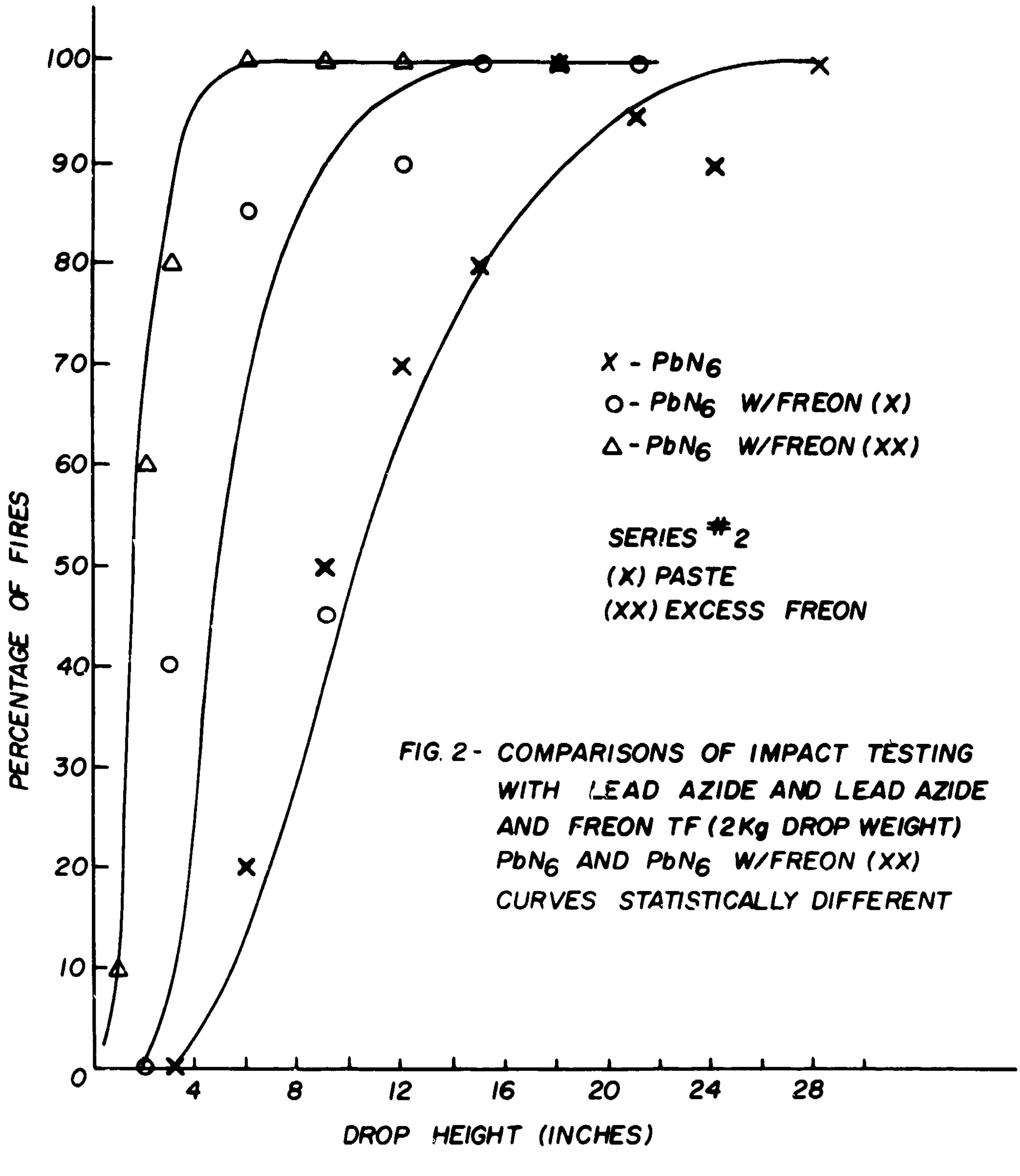


FIG. 2 - COMPARISONS OF IMPACT TESTING WITH LEAD AZIDE AND LEAD AZIDE AND FREON TF (2Kg DROP WEIGHT) PbN_6 AND PbN_6 W/FREON (XX) CURVES STATISTICALLY DIFFERENT

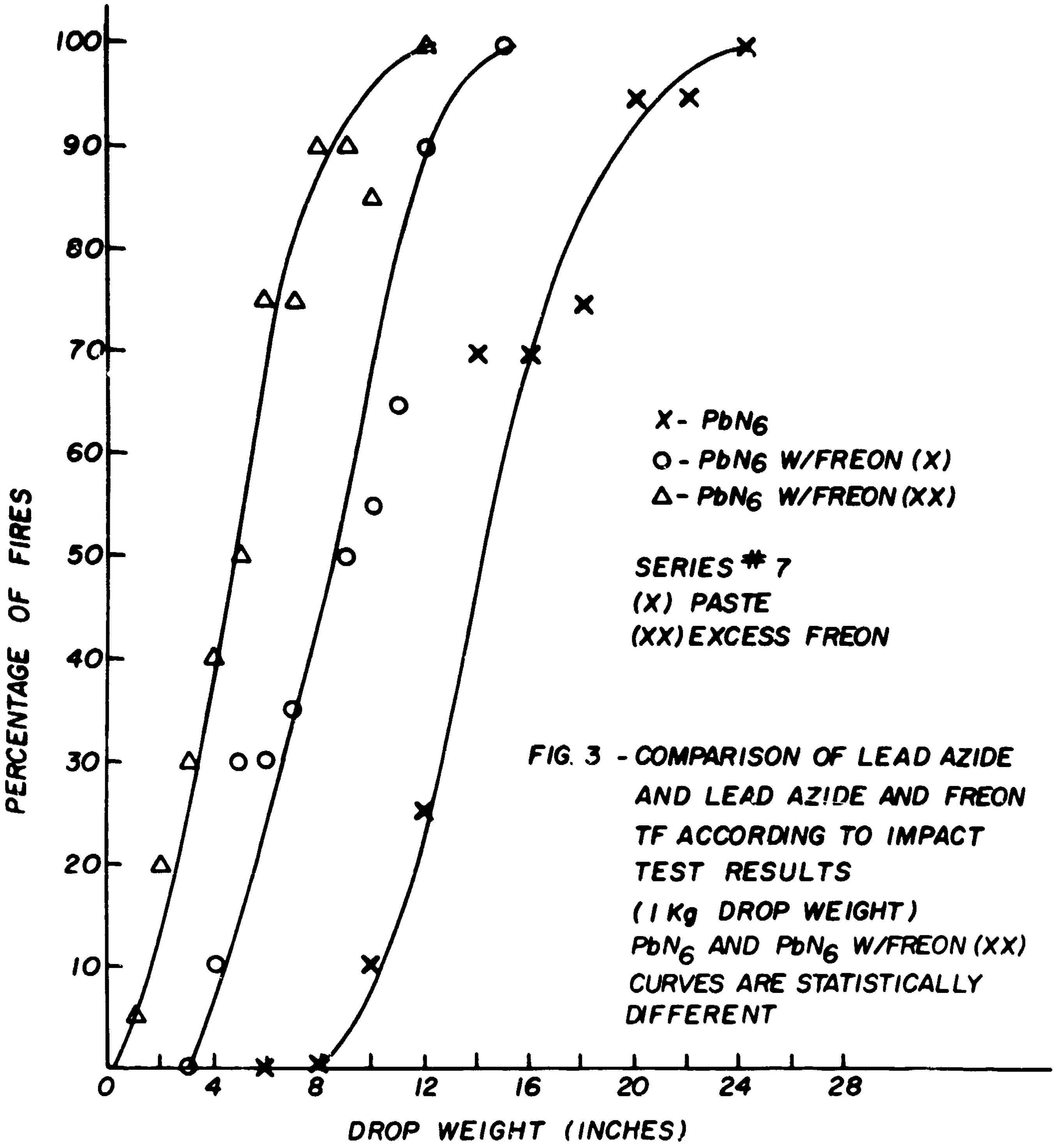


FIG. 3 - COMPARISON OF LEAD AZIDE AND LEAD AZIDE AND FREON TF ACCORDING TO IMPACT TEST RESULTS (1 Kg DROP WEIGHT) PbN_6 AND PbN_6 W/FREON (XX) CURVES ARE STATISTICALLY DIFFERENT

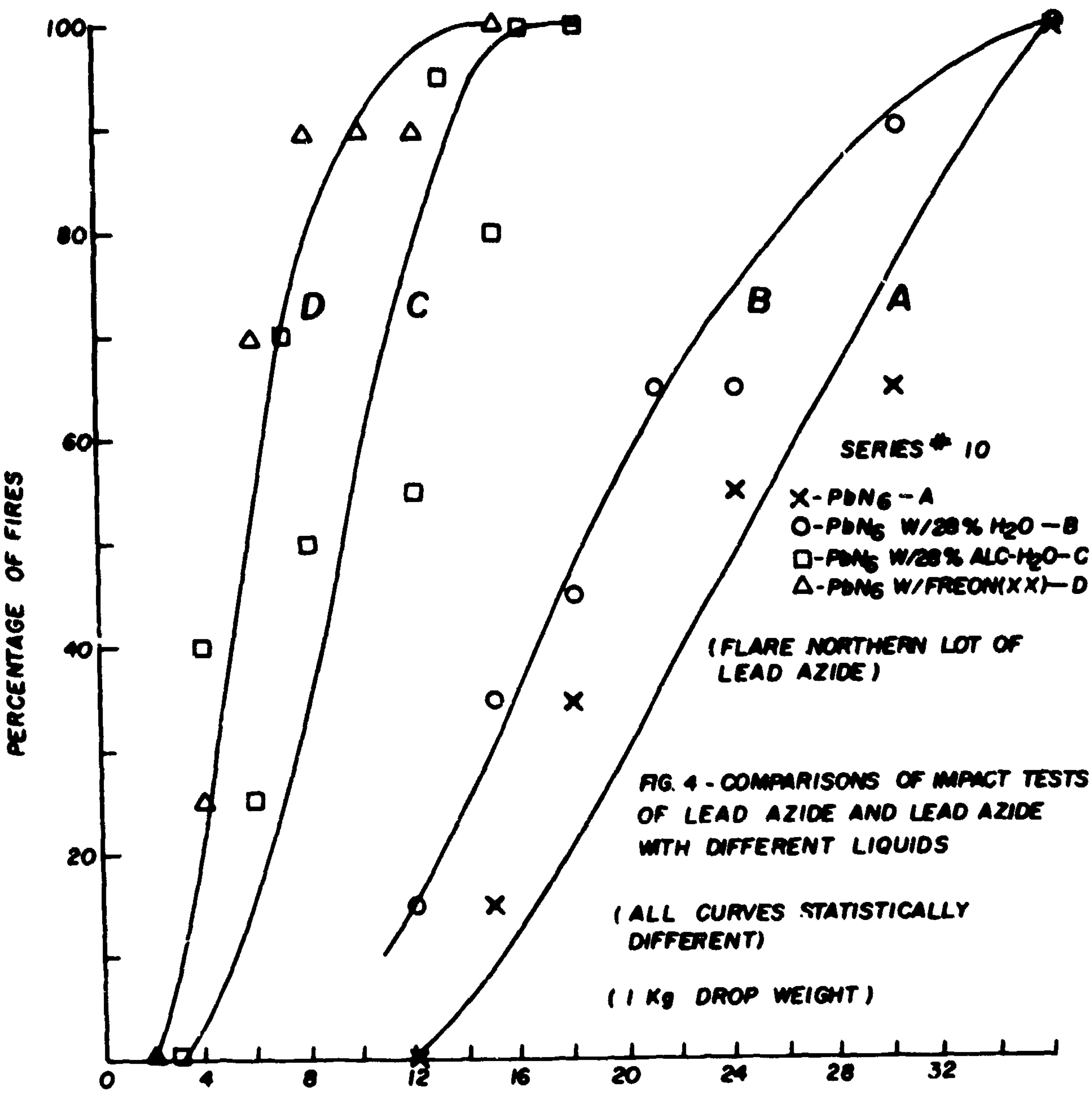


FIG. 4 - COMPARISONS OF IMPACT TESTS OF LEAD AZIDE AND LEAD AZIDE WITH DIFFERENT LIQUIDS

(ALL CURVES STATISTICALLY DIFFERENT)

(1 Kg DROP WEIGHT)

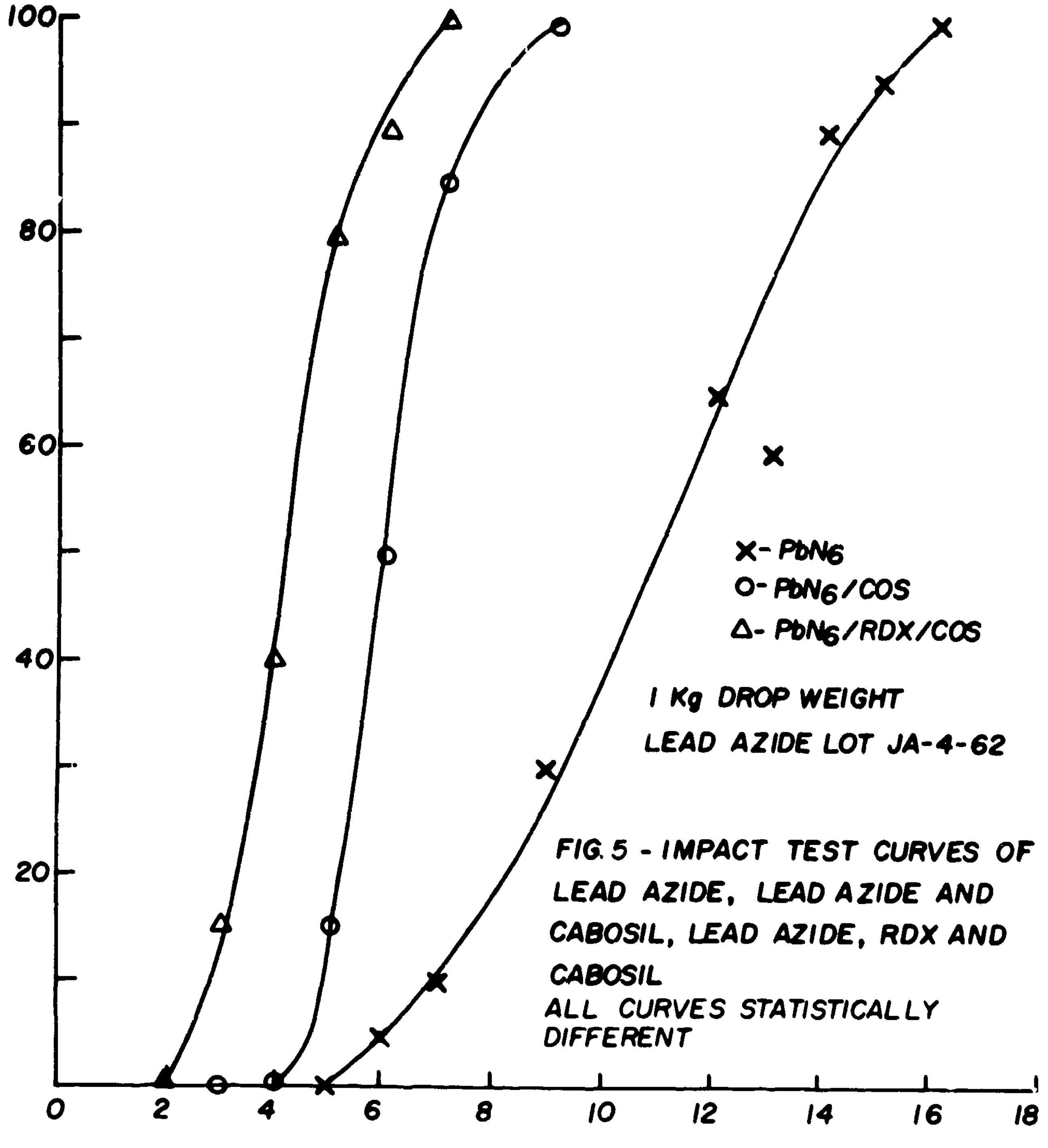
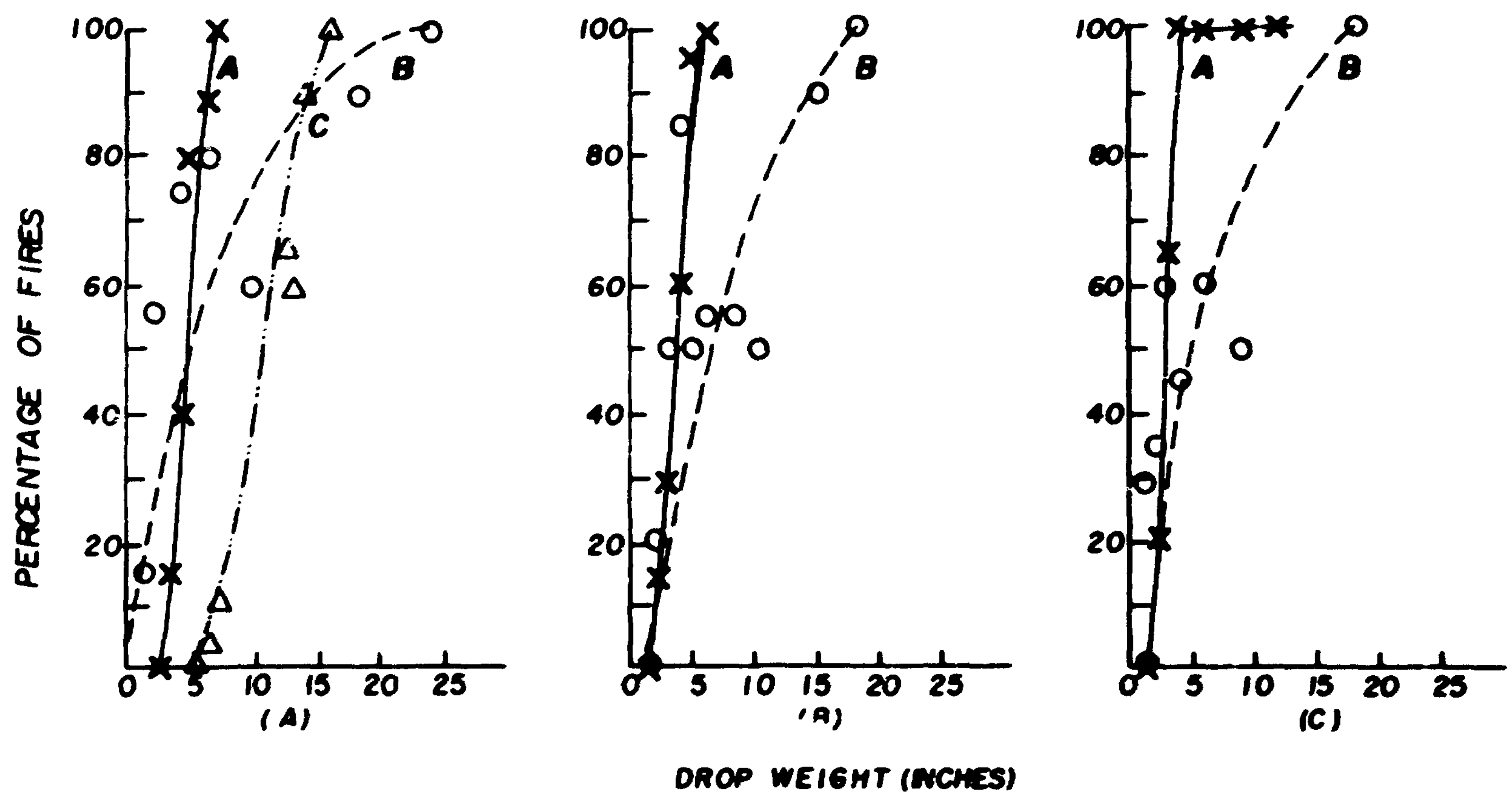


FIG. 5 - IMPACT TEST CURVES OF LEAD AZIDE, LEAD AZIDE AND CABOSIL, LEAD AZIDE, RDX AND CABOSIL
ALL CURVES STATISTICALLY DIFFERENT

FIG. 6 - IMPACT TEST CURVES OF LEAD AZIDE, RDX AND CABOSIL DRY AND WET WITH FREON TF (SERIES #15)

X - PbN_6/RDX/COS (A)
O - PbN_6/RDX/COS W/FREON (B)
Δ - PbN_6 (C)

NOTES — 1-MANY OF FIRES (~50%) IN (B) WERE VERY WEAK AND LOW ORDER
2-FIG. (C) STATISTICALLY DIFFERENT



INVESTIGATION OF "STATIC" ELECTRICAL PHENOMENA IN LEAD AZIDE HANDLING

by

Messrs. Jack R. Polson and H. A. Hanna
Mason & Hanger-Silas Mason Co., Inc.
Burlington AEC Plant
Burlington, Iowa

The presentation consisted of a brief summary of Technical Report No. 98-A* which outlines an investigation of a series of incidents involving the automatic dispensing of lead azide. The results of this investigation show that, under certain conditions, lead azide can be detonated by quantities of static electricity which are far too low in energy to produce visible or audible sparks or arcs. The electrical detonation sensitivity of lead azide is so extreme that it is imperative to the safety of any handling or loading operation that all possible steps be taken to minimize the generation and accumulation of static electricity.

It was also shown that although the handling of freon-wet lead azide is to be preferred to the dry state, freon does not necessarily reduce either impact sensitivity or electrical sensitivity.

In addition to the summary of Technical Report Number 98-A, a resume was included of the work which has continued after the publication date. This work was primarily concerned with the development of methods to eliminate or reduce the generation of static electricity during handling and loading operations. The use of very thin metallic films applied by vacuum deposition techniques was found to be effective in reducing static electricity or non-conducting materials such as Lucite operational shields, plastic bottles, etc. These metal films may be thin enough to allow the transmission of visible light to an extent better than 90% while reducing static electricity better than 99%.

*"Investigation of "Static" Electrical Phenomena in Lead Azide Handling" Technical Report No. 98-A, 11 December 1967, Development Section, Process Engineering Department, Mason & Hanger-Silas Mason Co., Inc., Burlington AEC Plant, Burlington, Iowa 52601.

AMMUNITION LOADING AND ASSEMBLY-LOADING PROCESSES

Moderator: G. H. Cowan
Army Munitions Command
Picatinny Arsenal
Dover, N. J.

AMMUNITION LOADING AND ASSEMBLY-LOADING PROCESSES

SUMMARY

This session consisted of three formal papers together with discussion on the subject matter presented by attendees of the session.

The first paper, presented by Mr. W. R. McKeen, NAD Crane, Indiana, described the facility for loading MK 82 bombs with MINOL-2. A paraphrase of Mr. McKeen's remarks is attached. Of particular interest to the group was the description of the method for conveying ammonium nitrate (NH_4NO_3) within the facility.

The second paper was presented by Mr. M. Sitzmann, NOL White Oak, and concerned the compatibility of Pentolite with TNT. Based upon the tests conducted, it was recommended that careful control be maintained to limit the acid content of the explosive to no more than 0.004%.

The third and last paper was presented by Mr. W. McBride, NOS Yorktown, Virginia, who discussed warhead loading advances by the Navy. Three types were discussed.

a. Cast loaded Cyclotols
b. Press loaded PBX's
c. Cast loaded PBX's

Originally, Mr. McBride's paper was to be more extensive, but security arrangements somewhat limited his presentation. However, the trend toward the wider use of RDX and HMX-type explosive was clearly indicated.

TYPICAL NAVY MINOL-2 LOADING FACILITY

by

Wm. R. McKeen, Naval Ammunition Depot, Crane, Indiana

Good morning gentlemen! This is my first opportunity to attend an ASESB Safety Seminar, and it has certainly been interesting so far. I look forward to making many new pleasurable acquaintances.

I am only going to talk for about 10 minutes. I have put together a short presentation on the Navy's approach to the equipment and processes to be used for loading of bombs with MINOL-2 explosive.

Briefly, the Army selected MINOL-2 as an alternate explosive filler for bombs they are loading for the Air Force. Since the Navy loads bombs for the Air Force also, this required facilities be made available in-house for MINOL-2 loading. NAD's Crane and McAlester were selected as the two activities in which to convert part of the facilities for MINOL-2 cast loading. After preliminary studies and considerable discussion, it was decided that the Navy would equip itself with the facilities I am going to describe.

First, let me digress a moment and discuss basic processes:

1. The Army uses the stick pelleting process. Grid melting equipment is used to provide molten TNT for the start of a batch. Additional solids are added to complete the batch. Temperature is controlled downward to a pouring temperature. The bombs are partially filled at a filling station with the molten explosive, then moved to a second station where large rods or stick pellets are inserted. Finally at a third station, solid scraps are added and a final pour of molten explosive is made to bring the total explosive height to a specified point. The stick pellets and the scrap are added to reduce to a minimum any cavitation due to

shrinkage of the explosive during cooling, in order that maximum density is obtained.

2. The Navy uses the straight pour process - that is we fill the bombs (Navy and Air Force) to within 4" of full, and after a timed period to allow a cooling period, depending on the size of the bomb, we crust vent and add a final pour of molten explosive to the finished height. The important point is that only solids are added to the kettle, and the temperature of the batch is regulated upward to the freezing temperature. This minimizes the total shrinkage. Because of the use of stick pellets, the Army does not require as close a control on their batching temperatures. This straight pour technique has been one of the major reasons for the Navy's ability to provide the tremendously high bomb schedules for the SEA conflict.

Experience from World War II in the loading of AMATOL and AMINOL points out two important factors:

1. $AmNO_3$ is hygroscopic (absorbs 32% its weight in H_2O in 24 hours at 90% RH; absorbs 14% its weight in H_2O in 24 hours at 76% RH) and must be controlled in an atmosphere that will eliminate water absorption (heating).
2. $AmNO_3$ goes through a phase change at 185°F. which results in crystal growth. If a MINOL-2 batch was allowed to reach 185°F. or over, and was poured into a bomb, the growth in crystal size of the solid $AmNO_3$ could cause molten TNT to be forced out of the explosive at any joint or seam. (R&D Yrktn).

With these thoughts in mind then - I'll continue and discuss our facility design.

First Chart

Here is a simple plan view of a Navy standard cast loading plant. These plants are still called "mine fill legs" by the operating people since they were originally designed and used for the filling of mines during WWII. What you see is only half the plant. The other leg is exactly the same and leads away from the inert preparation building the opposite way.

Generally, the line starts in inert preparation where bomb cases are hot melted and put in cable cars for transport to the filling building. Flaked explosive and metal powder ($AmNO_3$ never used) are brought to the second deck of the fill house where they are mixed together during melting in a kettle. The batch is dropped by gravity to the bombs. The cart is then transported to the cooling shed for cap-off, palletizing and loading in truck or railroad car.

Second Chart

To batch and cast MINOL-2 the big change comes about in the filling building. Because of our need to rigidly control our batching temperature, it was necessary to install a preheater for the $AmNO_3$. We did this here along side the filling building second deck. The preheater is heated with a liquid called "THERMINOL" which is raised to temperature by an oil-fired burner (Propane tank gas pilot light) in a heating station located on a concrete pad along the cable car way (135' from filling building). A belt conveyor was installed to bring the bagged $AmNO_3$ up from the nitrate building.

Third Chart

Here is an artist's conception of our filling building equipped for MINOL-2 batching.

The bagged nitrate is brought up on a belt conveyor. An operator slides

STANDARD NAVY HI-EX CAST LOADING PLANT

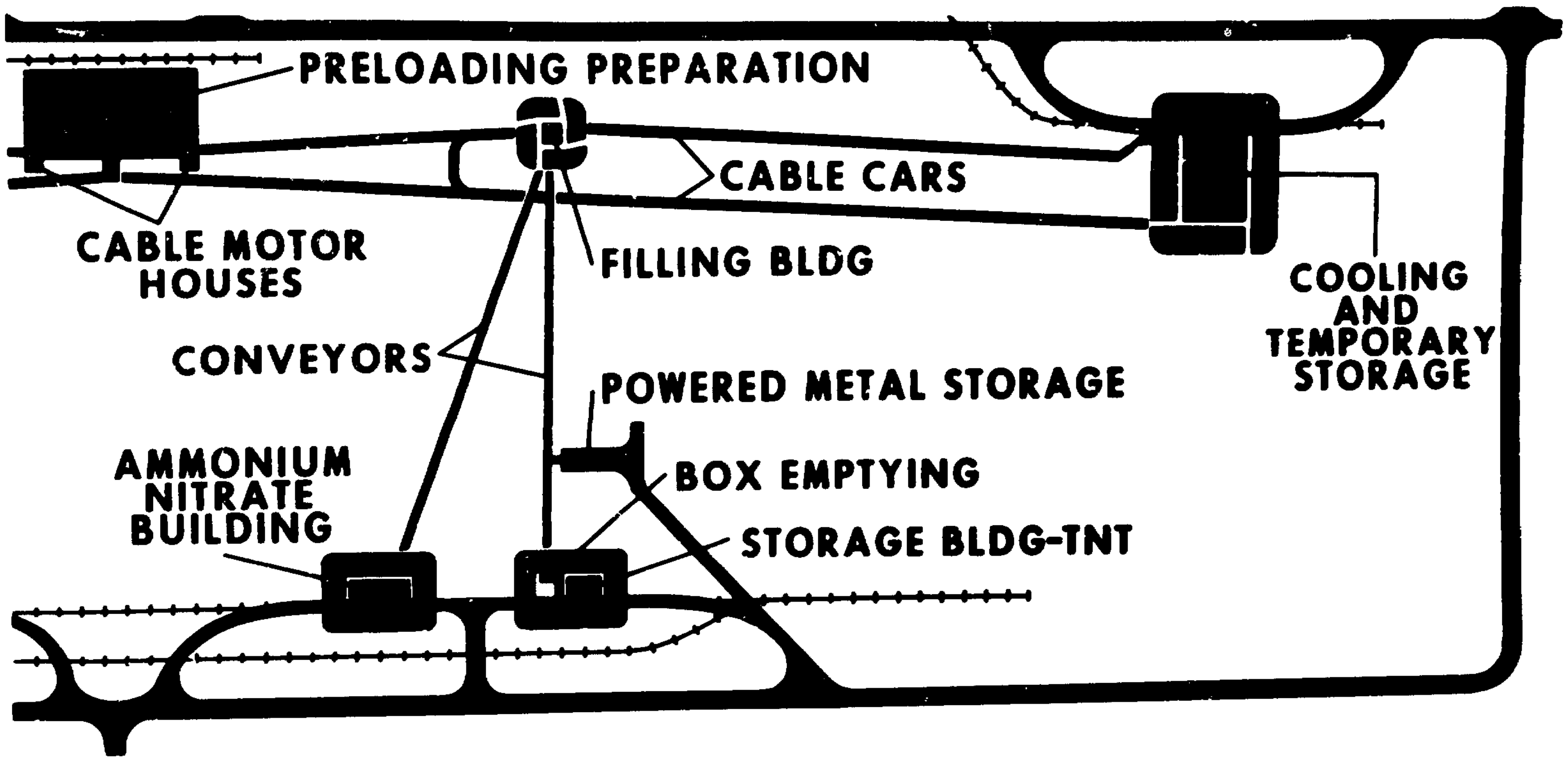


Chart 1

ISOMETRIC VIEW OF MINOL 2 FILLING BUILDING

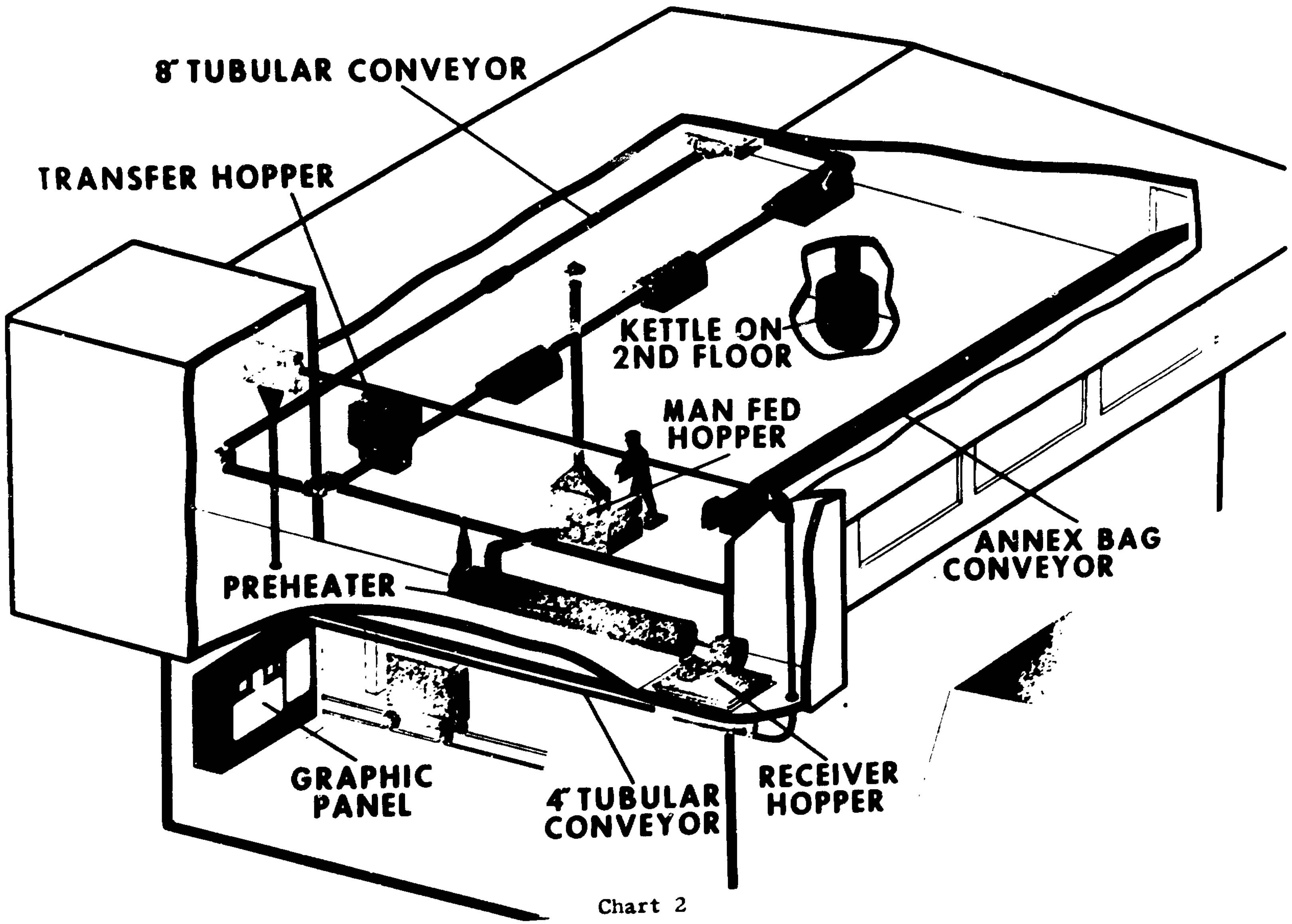


Chart 2

LAYOUT OF STANDARD FILLING BUILDING MODIFIED FOR MINOL

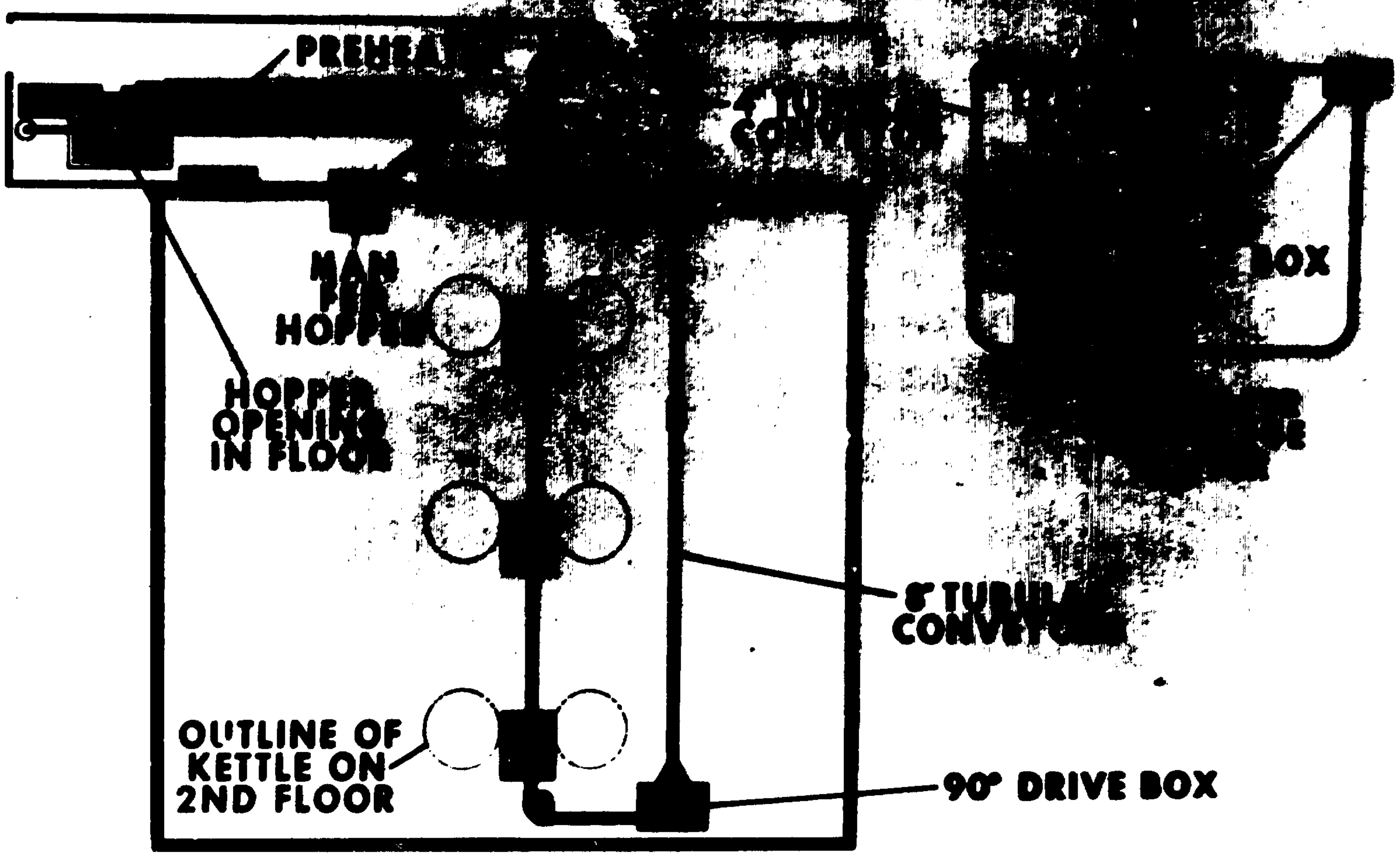


Chart 3

the bag into this hopper where a crusher breaks up lumps and drops the fines into a screw conveyor for transport to the preheater. The preheater is equipped with several sensors designed to control the $AmNO_3$ to 176°F. Overheating causes the 350°F. Therminol to bypass the hot section. If the temperature continues to rise the sensors will cause the Therminol to purge itself and return to the tank. The hot nitrate is screened upon leaving the preheater through this hopper and delivered to this vertical tubular conveyor at a rate of 200#/minute. The vertical conveyor (4" dia.) delivers the material to a second horizontal conveyor (8" dia.) through a transfer hopper. Final distribution is made at a rate of 600#/minute to scales located over the kettles. Each scale services two kettles by means of a flapper valve. When a kettle operator below signals for $AmNO_3$ a flapper opens the chute under the scale for his kettle. The conveyor delivers the material to the scale which weighs and dumps 50 pounds of $AmNO_3$ every 15 seconds until 25 dumps have been made (1,340 lbs.) into the kettle. The conveyor closes (allowing recharging of the transfer hopper) until another kettle operator signals for the next batch.

During breakdowns the $AmNO_3$ can be recirculated through the preheater from the 8" conveyor or dumped out of the system. The controls on the equipment are electrical and automatic. Some of the cabinets are purged with N_2 to provide intrinsic Class II E, F and G ratings.

Gentlemen, this concludes my talk. I wish I could tell you more about actual operation but the installation at NAD McAlester is being fired up this week and NAD Crane isn't to start until next week. Thank you.

BARRICADES FOR BUILDING SEPARATION AND AIRCRAFT PROTECTION

Moderator: Kenneth Kaplan
URS Systems Corporation
Burlingame, California

BARRICADES FOR BUILDING SEPARATION AND AIRCRAFT PROTECTION

SUMMARY

The specialist session of 13 August 1968, began with a summary presentation of information currently available on effectiveness of barricades. For barricades in the immediate vicinity of an explosive source, small-scale tests (with explosive weights ranging between ¼ lb and 250 lb) and full-scale tests (with explosive weights ranging between 6700 lb and 500,000 lb) indicated that such barricades had but a limited effect on air blast. Three examples of the results of such tests are shown in Figs. 1 - 3. It appears that barricades with sloping faces had no discernible effect on air blast overpressure; that barricades with vertical faces tended to increase overpressures somewhat at intermagazine* distances, to decrease overpressures somewhat at inhabited building, and passenger railroad and public highway distances*, and to have virtually no effect on overpressure at intraline distances*; and that barricades with vertical faces tended to decrease air blast impulse somewhat at all the named distances. The decreases in air blast overpressure or impulse are far smaller than those inferred by Instruction 4145.23 which generally permits the named distances to be reduced by a factor of two below those given for unbarricaded distances, if the stored explosive is provided with a barricade.

---

* Intermagazine, Intraline (operating building), inhabited building, and passenger railroad and public highway distances are those designated in DOD Instruction 4145.23 as being minimum safe distances between explosives stored in a magazine and the facilities at which the designated functions are performed.

Much less information is available on the effects of such barricades on missiles generated by an explosion but there appeared to be enough to infer a substantial personnel hazard at inhabited building distances, the degree of which would not generally be affected by a barricade.

The only information presented on the effect of barricades located in the immediate vicinity of targets (as distinct from those in the vicinity of the explosives) indicated that barricades or revetments with vertical interior faces that completely surround a target, may cause an increase in overpressure at the target because of internal reflections.

In the discussion period, it was brought out that even in those cases in which overpressure was increased on internal reflection dynamic pressure should be greatly decreased, in which case targets vulnerable to translation would most likely show decreased damage.

It was the sense of the entire group that barricades near a target tended to be far more effective against both air blast and missiles than barricades near an explosive source. Even with such barricades, however, each case should be considered alone. Suggesting this is the above-mentioned possibility of a barricade increasing blast overpressure, and the relative ineffectiveness of a barricade (unless very high) against relatively high trajectory missiles. (These are the missiles that would be projected to maximum range.)

The possibility that the energy absorbed in destroying a barricade might significantly alter the air blast in the far field was discussed. It was noted that the tests conducted with and without barricades in which the barricades were destroyed did not seem to bear this out. There probably would be some effect, but the fact that substantial quantities of material are ejected in forming a crater even without a barricade, and that redirected energy had a chance to redistribute itself were cited as possible reasons for the minor effect.

Protection afforded at intermagazine distances was discussed. It seemed certain that barricades near the explosive source would give substantial protection against low flying missiles (unless the barricade itself became a missile source) as would barricades near the target. However, barricades near the source appeared to worsen (if anything) the blast field. (Though impulse was reduced, peak pressure appeared to increase.)

The type of damage sustained by a house subjected to the shock wave from a 10,000-lb charge and from two 5,000-lb charges detonated with but a short time delay was described. Flying glass was noted as the major hazard.

There was considerable discussion of how the quantity-distance relationships of DOD Instruction 4145.23 might be changed as a result of the findings described above. An interim measure might be to adopt either the "barricaded" distances or the "unbarricaded" distances from the instruction by deciding on an acceptable level of damage. A better approach would be to review the reasons used for choosing these distances; to establish firmly the characteristics of shock pulses and missile field at the various distances (especially the inhabited building distance; to adopt, through test and/or analysis of data, firm acceptable damage criteria; and to establish new quantity-distance relationships from this program.

Finally, the change of blast pressure with distance was discussed. It was noted that information was lacking on the blast field in the vicinity of a barricade. It appears certain that peak pressures should be reduced quite close to a barricade, but where the crossover point occurs - i.e., where peak pressures begin to exceed those that occur with no barricade present — is uncertain.

Mr. William Filler of U.S. Naval Ordnance Laboratory acted as co-moderator of the specialist session of 14 August 1968. After a discussion, similar to that of the previous day on effectiveness of barricades, Mr. Filler described the problem of "simultanaity" of detonation. (Two or more charges close to each other may act as a single larger charge even though there is a finite time between

detonations.) He described tests carried out at China Lake in which two 5,000-lb charges, located in adjacent bays of a storage configuration, but with a dividing wall designed to prevent propagation of detonation, were detonated with a delay between them of approximately 24 msec. Pressure measurements showed a single pulse whose characteristics were similar to those from a single 10,000-lb charge. Damage to a structure located at the barricaded inhabited building distance (from DOD Instruction 4145.23) was slightly greater from the two 5,000-lb charges than from a single 10,000-lb charge.

In the discussion period, the use of 24 msec as a delay time was questioned. It was noted that a value of about 20 msec represented an approximate upper bound on the time during which propagation of detonation was likely to take place in such a configuration. If pressure pulses from the two charges coalesced with such a time delay, they were even more likely to coalesce with shorter delays. The tests did not document where coalescence took place.

It was also pointed out that small-scale tests had indicated that delay times could be considerably greater and coalescence would still take place.

Building damage mechanisms were also discussed. It was not clear to those assembled that coalescence was an adequate criterion for determining whether two charges could be more destructive than a single charge. A pulse with two or more peaks could well cause damage similar to that from a pulse with a single higher peak, if the impulse of the two pulses were the same.

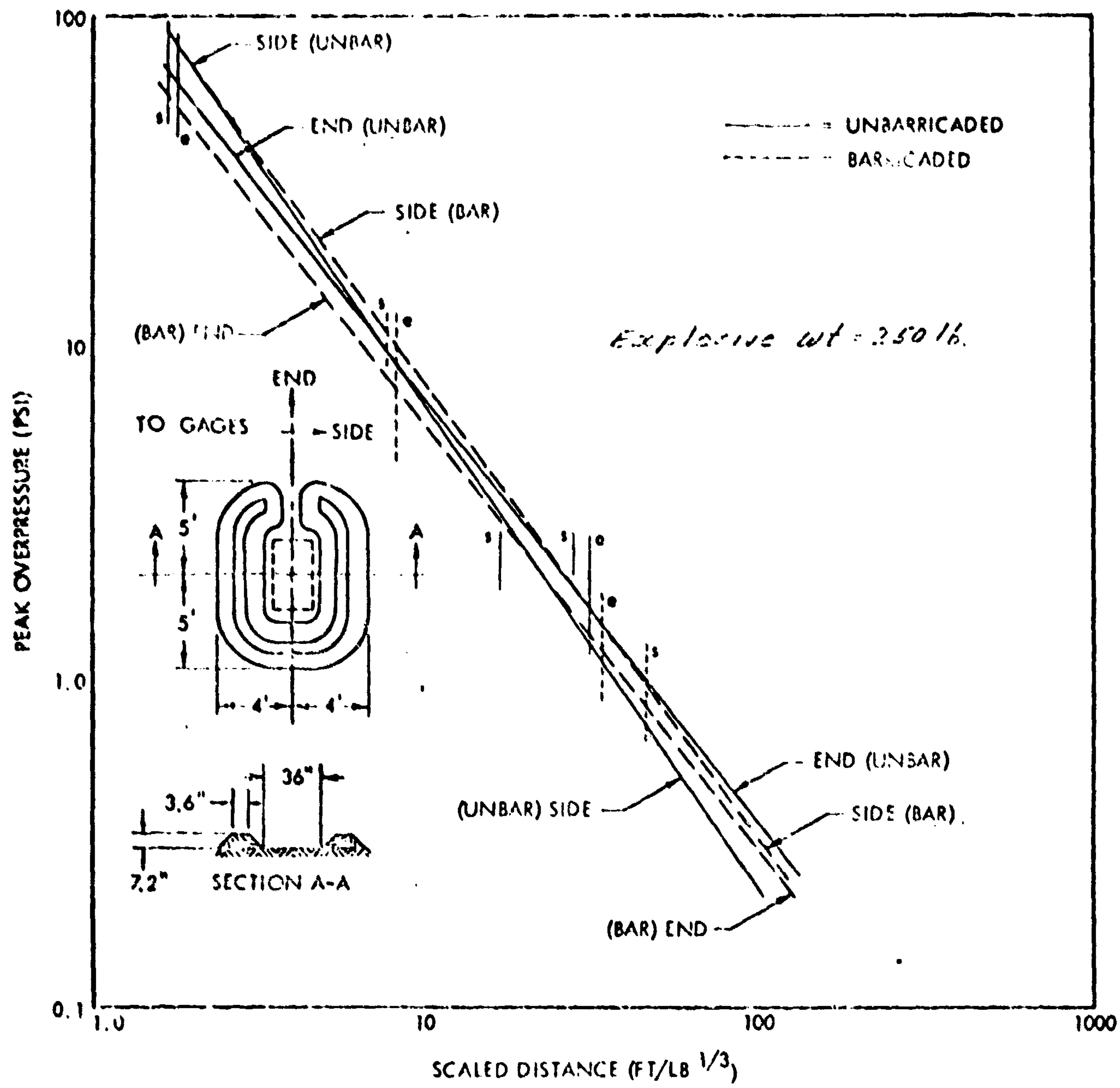


Fig. 1 Arco Small-Scale Revetment Tests. (Vertical bars indicate experimental spread; solid bars for unbarricaded data, dashed bars for barricaded data, "s" = side gages, "e" = end gages.)

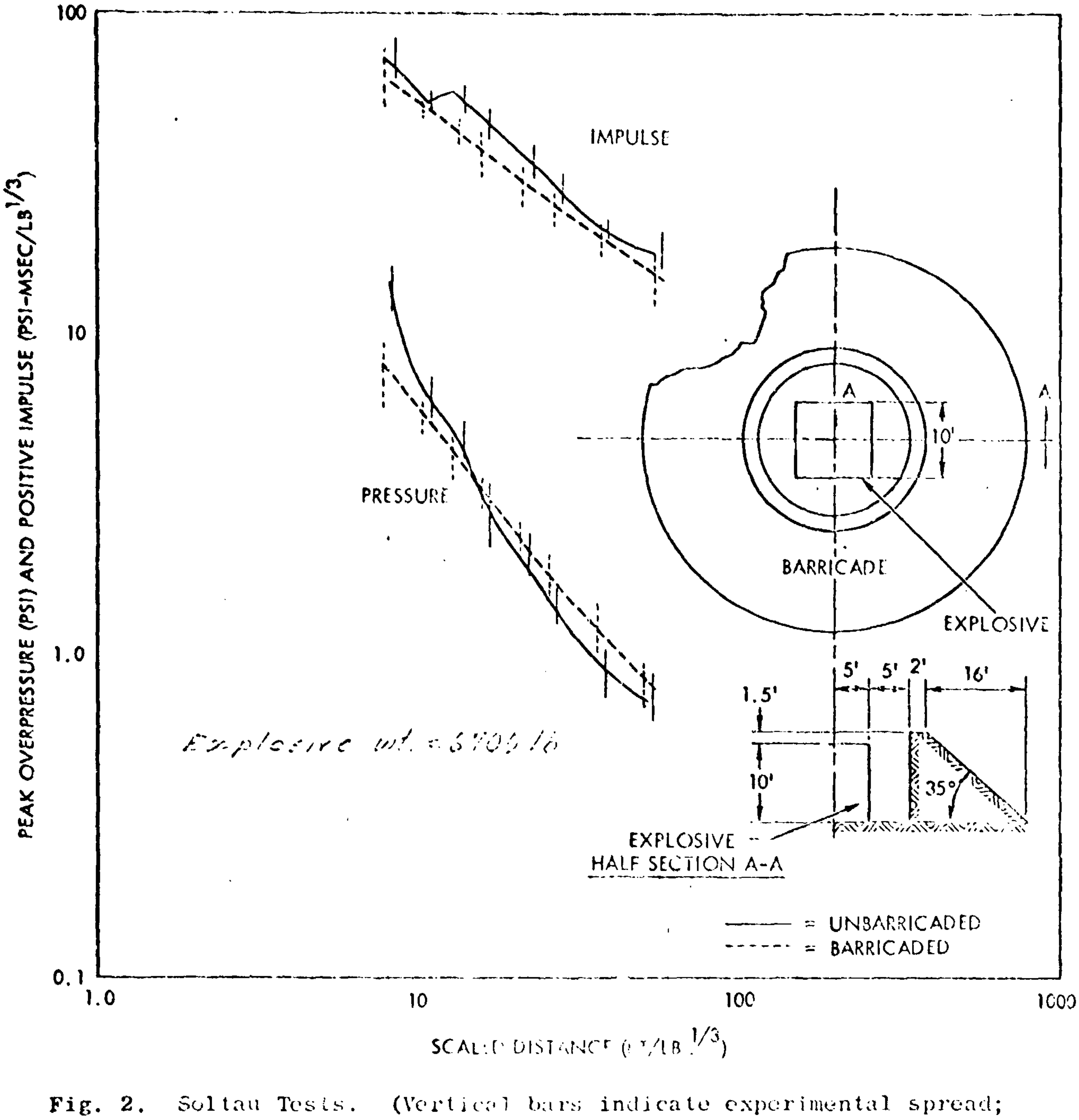


Fig. 2. Soltau Tests. (Vertical bars indicate experimental spread; solid bars for unbarricaded data, dashed bars for barricaded data.)

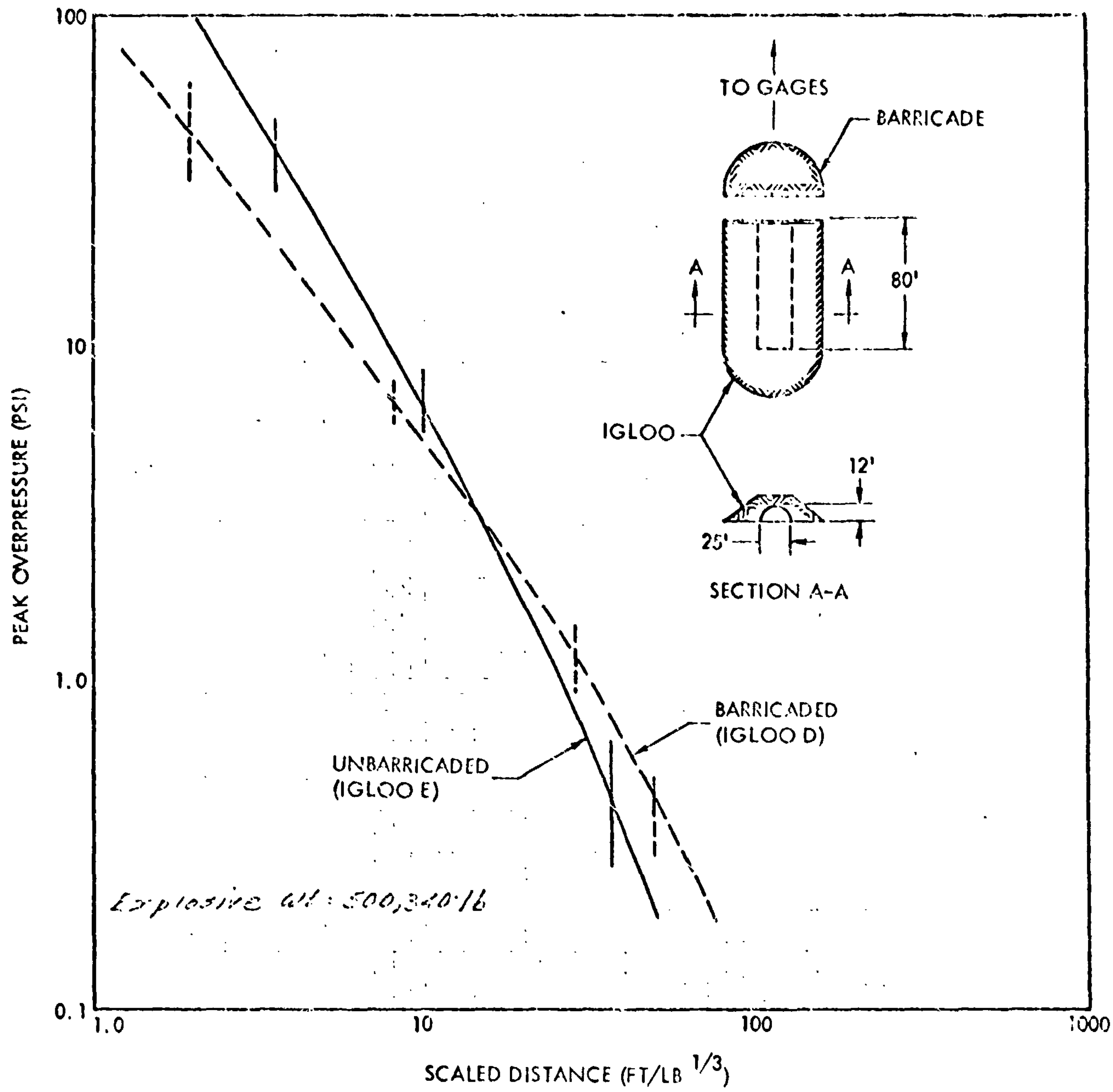


Fig. 3 Arco Full-Scale Igloo Tests. (Vertical bars indicate experimental spread; solid bars for unbarricaded data, dashed bars for barricaded data.)

BEHAVIORAL STUDIES OF EMPLOYEES INVOLVED IN EXPLOSIVES OPERATIONS

Moderator: E. W. Van Patten
Safety Director, US Army Munitions Command
Dover, N. J.

BEHAVIORAL STUDIES OF EMPLOYEES INVOLVED IN EXPLOSIVES OPERATIONS

SUMMARY

In late 1967, the US Army Munitions Command (USAMUCOM) awarded a contract to the American Institutes for Research (AIR) to conduct a study of the behavioral compromises of safety.

All explosives manufacturing installations within USAMUCOM were selected to participate in this study. Since this was a research and development program, it was decided to survey from 100-300 employees and supervisors at each installation. The selection of the employees and supervisors to participate was left at the discretion of the installation. However, it was recommended that the bulk of the participants be selected from explosives operating areas with a token quantity from storage areas, maintenance and other support facilities.

The contractor was requested to design the survey instrument. The original survey instrument was tested at two installations and found to be inadequate. The USAMUCOM project officer worked closely with AIR to perfect another instrument. This instrument was tested at two installations and with slight refinement was adopted as the final survey instrument.

Tentative findings from this R&D survey revealed that one of the basic problems was in the training of employees. This problem received immediate attention and many changes in the training programs have been made and are currently being assessed.

Detailed data pertaining to the study is in speech presented by Mr. C. P. Hahn.

BLANK PAGE

BEHAVIORAL STUDIES OF EMPLOYEES INVOLVED IN EXPLOSIVES OPERATIONS

by

Clifford P. Hahn
American Institutes for Research
Silver Spring, Maryland

For about a year and a half, the American Institutes for Research has been studying the problems of safety in Army munitions plants. We first conducted a feasibility study to determine whether approaches from a behavioral science point of view would provide information that would help the plants reduce accidents.

Perhaps a word about our general philosophy or rationale for work regarding safety is in order. We look upon accident phenomena as a sub-system output of a larger system designed to produce socially useful results. By its very nature, the accidental output has a negative influence on the over-all output of the larger system. Thus in industrial situations, production is the output goal of the system. Too often, safety studies and analyses concern themselves only with the accident phenomena sub-system and give little if any consideration to the interactions between the sub-system outputs and the total system environment.

The concept of safety within a system is a long range one. If it exists, it allows the system to pursue its course toward the objective without interference, but its existence itself does not attain the objective. Thus the safest munitions plant is one in which no production is taking place. On the other hand, the actions required to maintian a safe production environment often appear to, and in fact do in the short run, restrict the direct attainment of the production goal. We believe that many of the behavioral actions that lead to accidents are caused by the inevitable compromises that must be continually made by personnel at all levels between the objectives of maximum production and minimum accidents.

A great majority of the accidents can be traced to unsafe acts. This has been known for a long time. It appeared to us that it was also important to know how often unsafe acts are committed that do not lead to accidents, why they are committed, and what is normally done about them.

With this in mind, we designed the study which started last September and is now nearing completion. In this study three separate forms have been administered to 4015 munitions workers. Before describing some preliminary findings I would like to describe the procedure and instrume[illegible] to you.

Normally we requested a sample consisting or workers and foremen on at 4:1 ratio. At each plant we surveyed maintenance personnel and line workers. MUCOM usually designated the particular lines to be sampled at each plant in order to have a good representation of the various types [illegible] operations.

The workers were surveyed in groups, apart from their supervisors, and workers from several lines were often surveyed together since we handled gr[illegible]s sometimes as large as 30-40 people.

The first instrument was an incomplete sentences form. This form differed slightly for workers and supervisors, but a number of questions are either identical or parallel.

In an incomplete sentences form the subject is given a set of sentences for which only the first few words are given. The instructions are to "complete these sentences to give us your opinion in your own words." This form served several purposes. Basically it is an expression of attitudes. It also seemed to be a good form for establishing rapport, since there were no "wrong" answers, and often workers came to the sessions fearing they were going to have a test. Finally, it afforded us an opportunity to estimate the literacy level of the group and to determine who would require individual attention. This form usually took 15-20 minutes to complete.

The second form contained some background information. No names were asked, but we did ask age, marital status, years employed at the plant, etc. This information will not be used to identify any individual, but to determine whether these factors are related to safety consciousness. Inside this form were questions relating to safety programs carried out at the plant, and questions concerning employees' attitudes toward such programs. This form usually was completed in 15 minutes.

Employees were then given an envelope containing 50 cards. SLIDE 1...

Each of these cards contained a brief description of an unsafe act or unsafe condition. The instructions were to sort the cards into two stacks--things the employee had seen during the past month, and things he had not seen during the past month. For example, if the card read "Using equipment without permission" the employee was to think back over the past month and decide whether he had seen anyone doing this. If he had, he put the card off to his right; if he had not, he put it off to the left. He then read the next card and did the same thing, until he had sorted all fifty cards.

At this point, we collected the card representing the things "not seen" We then asked them to turn over the stack of cards representing things they had seen, and answer the questions on the back. The questions on the reverse side first asked "How many times during the past month have you seen someone .(whatever the item covered) . ?"

Next, the respondent was asked to think about the most recent time he had seen it, and answer the remaining questions. These questions concerned what happened, why he thought the person did it, and whether anything was done about it.

Finally, the act, as most recently seen, was given a Danger Rating and Supervisor Action rating.

SLIDE 2....

The ratings were coded from a sheet provided with the cards. A Danger Rating of 0 was given if the act was "Not likely to cause an accident", 1 meant "Could easily cause a minor injury", 2 "Could easily cause a disabling injury", 3 "Could easily cause a fatality", and 4 "Could easily cause property damage."

Respondents were reminded that two ratings could be given, as for example, when an act could lead to both injury and property damage.

SLIDE 3....

The Supervisor Action scale was coded as follows:

0 = None

1 = Foreman or supervisor told employee to correct it

2 = Foreman or supervisor reprimanded employee

3 = Employee was disciplined (transferred, time off, fired)

4 = Foreman was reprimanded by his supervisor

5 = Don't know

Again two ratings were possible, as for example, when the employee was disciplined and the foreman was reprimanded. This would be for a very serious offense, and double ratings on Supervisor Action were not common.

This completed the employees' tasks. We surveyed at 20 plants representing both government and contractor operated plants. The results have been punched and are now being analyzed by line and by plant.

I would like now, to turn to some preliminary results from the study. First, I will report some of the findings from the Incomplete Sentences form.

SLIDE 4. . . .

This slide contains a percentage distribution of responses to the first sentence: I feel that safety in this plant ____________

RESPONSE		PLANT 7	5	3	1	2	4	6
Illegible, uninterpretable	01	3	2	3	4	1	3	4
As important as production	02		3	1	2			
Comes first, excellent, very good	03	30	20	26	8	29	12	15
Good, above average	04	25	19	14	21	22	21	14
Average, O.K.	05	10	11	5	7	8	20	14
Needs improvement	06	6	20	11	38	8	14	13
Poor, not followed	07	3	6	2	6	1	11	11
Important, necessary	08	14	11	19	5	19	3	15
Comes second	09	1	1	1		1		2
Too strict	10	1						5
Good and bad (specific rules or areas)	11		2	2	3	3	3	2
Other		7	3	14	5	6	9	2
Omit				1		1	3	1

Note that the plants have been assigned numbers. These numbers are based on the number of disabling injuries at these seven plants during the first seven months of FY 69. Plant number 7 had the lowest rank or fewest disabling injuries; Plant number 1 had the highest rank among these seven on disabling injuries, or the greatest number. This does not mean that these seven plants ranked highest in MUCOM on disabling injuries. The rank refers only to their rank among the first seven plants coded. Their selection means only that the forms were in the boxes of data opened first.

I think you will find a number of items of interest in these slides, but in view of the time allowed I will point out only some highlights.

It is particularly interesting to compare plants 1 and 7 in Slide 4. Look at row 03 and row 06. Workers at Plant 1 feel that safety needs improvement, and only 8% report that safety comes first at the plant. Plant 7 on the other hand has the reverse opinion. Plant 2 has some interesting statistics which will be apparent in other slides also. It has the second highest disabling injury record among these plants but the workers responses parallel more closely those of Plant 7 than Plant 1. We have a couple of hypotheses about this which we will be able to check out with other data still being tabulated.

<u>SLIDE 5</u>. . .

If I don't follow safety rules my foreman ______________

RESPONSE		PLANT						
		7	5	3	1	2	4	6
Illegible, uninterpretable	01	2		1	1		3	1
"Official" action: Writes me up; warns 1st, then fire	02	16	29	22	3	32	12	9
Scolds, reprimands, lectures, yells	03	18	17	9	14	17	18	20
Tells me, cautions me, shows me	04	42	36	48	62	39	41	41
Warns everyone, calls meetings	05	6	2	5	[illegible]	1	1	4
Does nothing, doesn't know	06	2	7	5	11	1	5	8
Gets unhappy, angry, upset	07	6	4	5	1	5	3	6
Denial: I follow rules	08	2				1	1	1
Other	50-1		1	4		1	5	7
Omit	99	4	3	1	3	1	[illegible]	2

In this slide note that Plant 1 has the smallest percentage reporting that any official action follows deviation from safety rules (Row 02). That plant is also highest on Row 06(Does nothing, doesn't know). It was somewhat

disappointing to see the low percentages for all plants on Row 5, since most deviations probably would apply to other work stations as well. Plant 7 ranks highest on this, although the differences are small.

There is a fairly high correlation between responses to Row 02 in this slide and those to Row 03 of the Slide 4. (I feel that safety in this plant.....)

SLIDE 6....

Morale in this plant RESPONSE		PLANT 7	5	3	1	2	4	6
Illegible, uninterpretable	01	10	7	11	3	4	11	2
Excellent, very high	02	25	16	14	16	18	7	13
Good, high	03	27	24	22	30	35	26	21
Average, satisfactory	04	11	14	14	20	12	16	21
Poor, low, bad	05	6	16	10	6	9	14	13
Very: poor, low,bad	06	3	8	5	5	3	3	9
Good and bad (area differences)	07	3	3	4	6	3	3	2
Could be improved	08	4	7	6	8	4	3	5
	Other	2	1	2	1	5	1	8
	Omit	10	4	11	4	8	16	5

We included this item because we thought it would give some interesting attitude data and because we thought low morale would be correlated with high horseplay. As it turns out we will probably not be able to use this item at all. Morale is a difficult word. Many people misunderstood it. One common misinterpretation was confusion with the word "morals." A number of workers asked if this is what we meant and responses on some of the forms indicated this misinterpretation. However, "high," "very good," "low," and other adjectives could apply to both morale and morals, and we don't know which was meant.

Another misinterpretation seemed to be confusion with "moral," as in "moral of the story," "Morale in this plant is safety first," or "Morale in this plant is do your job right" are examples of this confusion.

Finally, Plants 7, 3, and 4, which have a literacy problem had about 20% who either omitted the item or gave an uninterpretable response.

SLIDE 7....

Horseplay on my line ______________

RESPONSE		PLANT 7	5	3	1	2	4	6
Illegible, uninterpretable	01	2		2	3	3	1	2
Denial: Not allowed, forbidden	02	41	40	26	21	31	42	39
Very little, minimum	03	15	31	18	26	21	12	20
About average, normal	04	3	3	5	4	6	1	5
Done by only a few	05	4	1	10	7	1	2	4
Bad, often, too much	06	8	6	15	16	21	10	4
Getting better, only at breaks/line down	07	3	1	1	3	5		4
Criticism: Dangerous, foolish, unnecessary	08	13	7	16	5	4	11	14
	Other	2	1	4	6	4	5	3
	Omit	10	10	4	8	4	16	6

Slide 7 deals with horseplay. Two things stand out in this table. Plant 1 had the smallest percentage of denial, and on Row 06, Plants 1, 2, 3, and 4 have the highest percentages. Horseplay appears to be related to disabling injuries. But correlation is not causation. Horseplay is not the cause of the disabling injuries. Rather I think, it is the kind of envoronment that tolerates horseplay that will tolerate also the unsafe acts or conditions that lead to accidents.

In an earlier try-out of these forms we had one item which read "The company feels that safety__________." At the Safety Management Meeting at Picatinny last March, several representatives felt that the sentence was ambiguous since some workers would interpret company to mean their immediate foreman and other would assume it meant top management. We therefore used two sentences, as shown in Slide 8.

SLIDE 8. . . .

The Company / My foreman feel(s) that safety______.

		PLANT													
		7		5		3		1		2		4		6	
RESPONSE		Co.	Fore.	Co.	Fore.	Co.	Fore.	Co.	Fore.	Co.	Fore.	Co.	Fore.	Co.	Fore.
Illegible; uninterpretable	01	2	1	2	2	1	1	1	3			3	1	4	3
Comes first; a must	02	58	41	51	42	53	42	43	38	55	40	34	25	42	29
As important as production	03	3	2	2	1	1	1	2	2	1	5		3		
Comes second; after production	04	3	5	8	10	3	8	6	6			4	6	12	13
Important; essential	05	20	27	24	27	20	19	28	19	22	25	31	25	21	24
Good; O.K.	06	2	2			3	3	4	5	1	1	5	2	1	7
Should be: enforced, practiced	07	4	9	5	6	9	15	6	11	8	6	7	11	2	8
Other		5	5	5	8	9	8	5	7	12	15	8	12	15	12
Omit		2	6	2	4	1	1	5	8	1	6	8	15	2	4

Now if you look at Row 02 of Slide 8 you will see that without exception the workers feel much more kindly disposed to the company than they do to their foremen. More of them think that the company feels that safety comes first than feel that the foreman has this attitude. It's not so much that they feel that the foremen thinks it comes second (Row 04) although there are some little differences there. "Important or essential" is the other big category. It was interesting to find that we could not categorize the responses to "I feel that safety______." with the same system used here. Comparing the categories on Slide 8 with those

on Slide 4 shows that a high percentage of workers used qualitative adjectives, such as good, average, and poor when describing their <u>own</u> attitudes but did not do this when referring to the foreman or the company.

<u>SLIDE 9</u>. . . .

I am / A foreman is most likely to take chances if ______________.

RESPONSE		PLANT 7 I	7 Fore	5 I	5 Fore	3 I	3 Fore	1 I	1 Fore	2 I	2 Fore	4 I	4 Fore	6 I	6 Fore
Intellegible, uniterpretable	01	5	5	1	2	6	5			8	6	3	5	4	1
Rushed, short of help, line too fast	02	35	40	35	38	30	44	43	50	19	31	23	23	48	49
No one watching, can get away with it	03	10	3	10	9	11	19	12	12	10	13	7	9	9	9
Denial: Don't take chances	04	9	7	17	9	4	3	11	4	13	10	22	14	4	6
Personal problem: Tired, angry, worried	05	8	2	5	3	8	4	5	1	3	1	1	1	6	6
Don't know rules, ignore rules	06	7	1	3	5	8	2	3	1	14	4	5	2	1	2
Someone in danger	07	3	4	3	8	2	1	3	4	8	8	3	5	4	9
Over-confident, thinks it's safe	08	9	7	10	8	11	3	7	3	12	5	12	6	9	2
Other		6	17	9	3	13	12	9	8	7	12	9	8	11	10
Omit		8	14	4	16	7	7	7	17	6	9	15	27	4	5

Slide 9 compares the responses to two sentences dealing with risk. Without exception Row 02 has the highest percentages. It is disquieting to compare this response with other data we have that suggest that there is almost constant push for production, often with lines short of help. This could mean that some workers feel [illegible]ey are constantly taking chances. And perhaps they are...

Row 08 has some percentages that appear too high for safety. Handling dangerous material is not an occupation that leaves room for workers to make personal decisions about short cuts, deviations, or risks.

It also seems that the percentages in Row 03 are excessive. It suggests that safety training has not succeeded in instilling a personal motivation to work safely, whether or not one is being watched.

The slides just shown deal primarily with safety. Now I would like to show you a few that deal with training and job performance.

SLIDE 10. . . .

I could have learned my job easier if__________________.

RESPONSE		PLANT 7	5	3	1	2	4	6
Illegible, uninterpretable	01	4	4	3	4	3	9	
More time; more/better training	02	44	53	47	55	56	39	58
Demonstrations first	04	3	3	9	5	3	5	
More cooperation from workers	05	2	2	3	1	3	2	
Personal handicaps: Education, concentration	07	15	3	11	4	6	3	5
Not moved so much	08		2	3	3	4	5	4
Better equipment	09	1	2	1		1		2
Had overview of job	10	2	5	5	5	4	1	4
Training was O.K.	11	3	6	5	4	6	8	7
Other		7	10	4	7	4	5	4
Omit		17	10	8	12	10	23	16

This slide shows the coded responses to this statement for the same seven plants. Note that Row 11 has a very small percentage of the responses. Nearly everyone had some complaint about training. Most plants felt that more time or better explanations would have improved the training.

Row 07 usually refers to the need for more education, e.g.... if I could read better, ...if I'd had more education, etc. Plants 7 and 3 are located in areas of higher illiteracy than the other plants in this group which explains the higher percentage of responses in this category.

SLIDE 11....

The trouble with SOP's is ______________________ .

RESPONSE		PLANT						
		7	5	3	1	2	4	6
Illegible, uninterpretable	01	5	4	7	4	5	9	7
Not used/read/followed	02	27	23	16	24	29	15	36
Unclear, not detailed enough	03	14	9	40	22	14	11	11
Denial	04	11	14	11	6	14	14	11
Not taught, not given to new workers	05	1	1	2	2	5	1	
Too detailed, too long	06	7	4	4	6	5	1	1
Not up-to-date	07	3	14	2	8	10	3	6
Written by people not familiar with the job	08	2	5					7
Not enough of them, don't have any	09	3	1	1	4	4	3	
Changed too often	10	1	4	3	4	1	1	2
Have to try job first	11	4		1	4			
Too strict, too limited	12	1	6	2	3	3	4	6
Everything	13	1	1	2				1
Other		3	2	1	3		7	3
Omit		16	12	8	10	9	31	8

Note that in Row 04 the smallest percentage who found nothing wrong with the SOP's comes from the plant with the greatest number of disabling injuries.

The responses in Row 02 appear too high to be consistent with safe operation. The nature of the deviations from SOP's should be explored. Plants 2 and 5 have rather high percentages in Row 07--Not up-to-date.

This slide and the last one deal with how the worker learns his SOP. With few exceptions we have found that the common practice is for new workers to be trained on-the-job by the foreman. We have a strong feeling, based on our findings to date, that a great many foremen are not trained in the art (or skill) of teaching and supervision. For one thing, their coded responses on the sentence that reads, "The trouble with SOP's is______ ." parallels those of the workers, shown in the last slide. Thus they too find SOP's unclear, changed too often, not followed, etc.

Some plants have a significant literacy problem. It is hard to believe that people who write at the level shown on our survey instruments can effectively understand and teach SOP's written by the type of highly educated people who write them. We understand that many people must approve SOP's and they actually work the jobs themselves, first with inert material and then with explosives before workers are allowed on the line. It seems to us, however, that there would be an advantage to adding one more step: having a foreman teach this SOP to the kind of person who will eventually have to work on that line. If SOP writers could observe this process they might develop insights that would help them prepare clear, meaningful SOP's.

SLIDE 12

Percentage based on N of 106

Item No.	% Selecting	Times Seen 1-4	5-9	10-14	15-19	20-24	25-29	30+	Omit
127	66	24	8	3	6	5		21	
120	61	30	9	7	2	3	1	8	1
115	54	21	7	5	2	4	2	10	4
103	48	27	8	3	4			7	4
104	42	25	7	4	3	1		4	
117	29	15	2	2	2			7	2
124	29	24		2	1			2	1
210	12	8	1						4
303	31	15		2	3	2	1	4	5
304	33	16	5	1	1			4	7
305	39	19	4	1	2			8	6
306	24	12	2		1	1		1	7

Percentage based on number of times selected

Item No.	Danger Rating None	Minor	Dis.	Fatal	Prop.	Omit	Supervisor Action 0	1	2	3	4	5	Omit
127	14	24	26	33	19	7	51	3	7	1	6	16	16
120	52	22	18	6	8	6	not applicable						
115	56	26	5	4	9	7	28	30	5		4	19	16
103	24	29	20	24	8	12	27	14	4	2	8	24	22
104	20	33	18	29	11	18	36	13	9	7		20	16
117	29	26	16	29	10	6	35	16	16	10	3	16	6
124	55	23		26	6		26	48	10			6	10
210		23	8	38	23	31	23			23		23	31
303	21	24	12	24	9	24	27	6	9		6	21	30
304	9	26	23	31	11	20	17	29	23			14	17
305	39	12	20	10	7	22	39	10	10			22	20
306	21	21	17	17	8	33	25	29	12			4	33

127 People working too fast
120 Work area short of help
115 Waste or scrap left in work area
103 Workers put on job who were not properly trained
104 Working while sleepy or drowsy
117 Not following correct procedure for doing the job
124 Fail to ground material or equipment
210 People working while drunk
302 Bringing or wearing forbidden items into work area
303 Too much explosive material on conveyor
304 Handling dangerous material in an unsafe way
305 Wearing own clothing under powder uniform
306 Waste explosives or other dangerous material in the wrong area

Supervisory training might reduce the frequency of response to the incomplete sentence that indicates SOP's are not used or followed. If enforcing compliance with the SOP's is part of the foreman's job, he should be taught how to do it and supervised to see that he does.

The last slide contains a breakdown of the responses on the incident cards. Remember, these cards were sorted into two categories: things seen and not seen during the previous month. This slide shows the responses of one line at one plant for selected incidents.

SLIDE 12....

There were 106 people surveyed on this line, and every one of the 50 items had been seen by at least one person. The items on this slide include the three items selected by more than 50% of the respondents plus items dealing directly with handling of dangerous materials, or particular problems which I thought might be of interest here.

You will note that the two items most frequently selected both deal with staffing problems. This is probably the clearest and most consistent pattern that emerges from the data on all forms. In addition, we were very often told by safety and production people that keeping enough people on the job to meet production requirements is the plant's biggest problem. It seems that production is a constant pressure and the real compromises with safety are most often tied to these production demands. Perhaps someone will someday have to verbalize the real question before it can be answered: Are we willing to risk the lives of production workers here to save lives in Southeast Asia?

The frequency with which these items were picked is fairly typical. On the average I'd say about 25-35% picked each item. I included item 210, People working while drunk because it was selected by 12% of the group. We included the item at the last minute to reduce printing costs. (The items were typed two to a page and then the paper was cut. This section had an uneven number of items so pulling the

blank would be a hand job). We wanted a "garbage item"--one that everyone would reject. As you can see, we did not get it, and I believe it is safe to say, it was picked by some workers at every plant. It does not appear to be compatible with safety, and workers seem to know this, as indicated by the zero entry in column 1 of the Danger Rating and 38% in the Fatality column.

Column 1 of the Danger Rating section has some other interesting points. Item 124 indicates that over half the people who had seen material or equipment not grounded did not think it would lead to an accident. Perhaps it is difficult to convince workers that electricity does not have to travel through wires!

It is disturbing to find 33% observing people handling dangerous materials unsafely (304). One worker even told us that workers on her line would "throw powder around and laugh about it." We often felt that workers were not familiar with the characteristics of the explosive material they worked with--Indeed, we occasionally heard workers ask each other "What kind of explosive is that we work with?"

If you will now look at the Supervisor Action section, first column, you will see that no action is taken about 25% of the time. It is comforting to see that only 17% of the foremen allowed workers to handle explosives unsafely (304). But 35% permitted workers to use incorrect procedures to do the job (117), and 36% allowed workers to work while sleepy or drowsy (104).

The additional questions on these cards will permit us to probe more deeply into the whats, hows, and whys of these findings, and hopefully to come up with some countermeasures that will help the plants come closer to the goal of zero defects.

SHIELDING OF PERSONNEL FROM EXPLOSION HAZARDS

IN LABORATORY AND PRODUCTION

Moderator: Stanley Wachtell
Picatinny Arsenal
Dover, N. J.

A brief comparison of the various methods of evaluation, the sensitivity or performance of explosives (Trauzel, drop, impact, card gap and TNT equivalency) shows that while each test has its purpose, none of them can be applied "across the board" to indicate the overall hazard involved in utilization of the material in question.

It is proposed that efforts by the ASESB in developing criteria aimed at the creation of standards for lethal fragments/unit area, be supported and accelerated and that increasing attention be devoted to developing hazards criteria appropriate to the significant characteristics of the propellants involved, for example:

1. Probability of or susceptibility of ignition,
2. Probability of communication to another reaction supporting material,
3. Probability of transition (from deflagration to detonation) if involved in a reaction,
4. Practicability of control actions such as suppression, deliberate low energy initiation, etc.
5. Fragment attenuation by frangible shielding.

In conclusion, we must realize that the days of absolute safety are past, if they ever existed. We can no longer double "reasonable" fragment radii to get "safe" distances, since we are fast running out of real estate (and money). We must assist the ASESB in establishing criteria which admit to a finite degree of risk and use our newly mastered skills and techniques to establish meaningful probabilities and to assure that we are aiming our attention at those factors which are likely to cause injury in a specific situation. In other words, we cannot double or half "safety distances" for adequate protection. We must evaluate the manner in which the five factors previously mentioned apply for each specific operation, choose those which are meaningful, in that situation, and if possible establish meaningful "degree of risk" figures. In today's real world "TNT Equivalency" is a useful tool; it is not a cure-all.

THE SAFETY FEATURES OF THE PICATINNY ARSENAL EXPLOSIVES LABORATORY

by

L. Avrami and H. J. Matsuguma
Feltman Research Laboratories
Picatinny Arsenal
Dover, N. J.

Abstract

The experimental layout of the Picatinny Arsenal Explosives Laboratory with especially designed and constructed safety features is described. Details are given on the design and construction of the explosion-proof laboratory hoods. Also included are the description and operation of a combustible gas detection system.

I. Introduction

About 11 years ago a severe explosion occurred in the old laboratory where explosives research was being conducted. One of the hoods in use, which was constructed of plexiglass and albarene stone, was completely demolished by the explosion of only 50 grams of PETRIN (pentaerythritol trinitrate). Fortunately no one was in the laboratory at the time of the explosion.

Shortly afterwards the construction of a new Explosives Laboratory was authorized and the personnel of the Laboratory were permitted to establish criteria for the layout of the building and the laboratories to be included.

II. Discussion

The Arsenal chemists and engineers collaborated in the design of the entire laboratory building, the explosion-proof hoods and the inclusion of a combustible gas detection system.

The layout of the laboratory building is a large square with laboratories on the outside and offices and stockroom on the inner-side. This is the case on three of the sides while the fourth side consists of the main administrative offices and a small conference room as well as the main entrance to the building. The laboratories and offices are separated by hallways which go completely around the building. Fourteen laboratories are on each of the sides connected to the front section and eight laboratories including an access for deliveries to the building and into the center of the square are in the rear section.

Each laboratory has 14 feet square floor space with the explosion-proof hood occupying the wall space the farthest away from the doorway (Figure 1). L-sh d benches with a sink are installed. The bench tops were deliberately kept bare of services so that all experiments are carried out in the hoods. Each laboratory was designed for one scientist and his assistant. Safety showers are installed in each laboratory as well as in the nearby hallways (Figure 5). Two eye fountains are located in each hallway except the one by the administration offices.

One portion of a hallway is used for the storage of gas cylinders (Figure 8). Sections are designated for full and empty tanks with proper strapping. This assures that the tanks are stored properly and can be properly tallied.

All of the building utilities are centralized in the utility room which is located in the central portion of the square abutting the front section. All the equipment for air-conditioning, heating, hot water, distilled water and vacuum are situated in this room which is easily accessible for repairs and maintenance.

On the three sides where the laboratories are located a blast perimeter fence is installed. This is situated about ten feet from the edge of the building and is about ten feet high

The explosion-proof hoods are constructed of steel with horizontally sliding removable doors of 5/8-inch butecite-cored lucite with steel frames. Eight such doors cover the entire 14 foot length of the hood.

It is three feet deep and five feet in height from the bench top level (Figures 3 and 4). The back panels are frames with plastic coated screens which will blow out if a detonation occurs (Figure 2).

These explosion-proof hoods were designed, manufactured and tested at Picatinny Arsenal. Proof-testing of these hoods was performed by detonating 100 grams of RDX explosive in a plastic bag located six inches from the center of a door about one-third the distance from the side wall. The explosive was initiated with a No. 8 blasting cap.

Each hood is fully equipped with the necessary services - sink, power (110V and 220V), pyrofax gas, compressed air, steam, vacuum, hot water, cold water, and distilled water. A distilled water outlet is located in the sink on the work bench. The controls for all these services are outside the hood. The electrical strip outlets are on the vertical frames and the other services have their controls just below the sliding doors. Each hood has its own exhaust system with controls at the light and power switch panel. Each hood is painted with acid-proof paint.

The explosive allowances for each laboratory are 50 grams for experiments in the hood and 150 grams of explosives for temporary storage. If the latter is the case no experiments are permitted in that hood.

Some difficulty has been encountered with ventilation according to U.S. Army Environmental Health Agency (USAEHA) regulations.

The hoods were designed with a makeup air curtain across the front face of the hood, up from the front of the table top. However, this gave a negligible velocity of air across the face. This was done so that no fumes could escape and also to prevent the loss of air-conditioned air. The USAEHA regulations require more than 100 cfm (cubic feet per minute) for this operation and the only way to accomplish this is to minimize the door openings and not to use makeup air. For the past six years no cases of toxic exposure have been reported except for two cases where these men had their heads in the hoods and inhaled HN_3 (hydrazoic acid). There have been at least ten (10) severe explosions in these hoods and in all cases only very minor or no injuries to the hands were the result.

Due to the central heating and the air-conditioning of the entire building, there exists a possibility that explosive gases can accumulate in the air ducts. To overcome this, each laboratory has a gas detector which reacts to combustible gases. The nomenclature on the gas detector is MSA Explosilarm Part No. 78500, 115 volt, 60 cycle one phase one ampere (Figure 6).

Each detector consists of two sample inlets in the laboratory - one suspended up near the ceiling and one near the floor, both of which are connected to a pump in the detector (Figure 7). The two inlets are so placed as to assure the pickup of light and heavy gases. The detector is a 2-level, 2-component system which is calibrated by using petroleum ether. At 20% L.E.L. (Low Explosion Level) (hydrocarbon calibration) the larger unit of the system sounds a horn and flashes

a red light so that local action can be taken. At 40% L.E.L. the smaller unit cuts off the electrical power to the entire building with the exception of the detectors and the hood exhaust systems. The latter systems automatically start on full exhaust when the detector trips at 40% L.E.L. and all the laboratory hoods start to exhaust so that the entire building will be exhausted. This action is taken to prevent the accumulation of combustible vapors in the building.

Fire alarm switches are located in each hallway. These are easily noticeable since they are in the center of large circles whose areas are painted red.

You are welcome to come and visit our laboratory and we offer our assistance if you are contemplating undertaking the construction of similar-type installation.

ILLUSTRATIONS

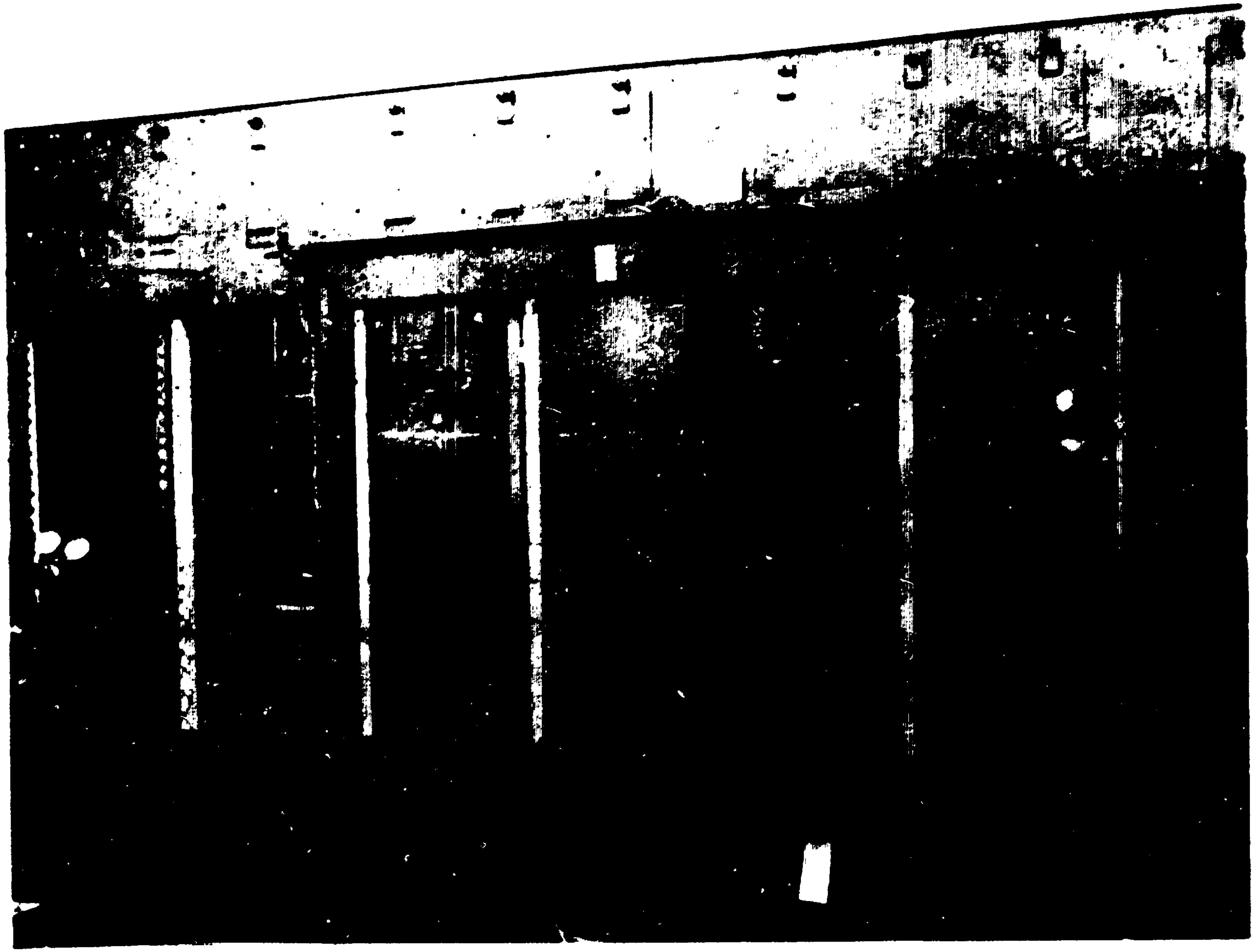


Figure 1 Typical Hood as Found in Explosives Laboratory. Hale Building, Picatinny Arsenal

Figure 2 — HN_3 Generator Bay Showing Holes in Back Screen Resulting from Two HN_3 Generator Explosions

Figure 3 Details of Door Installation Showing Steel Frames (White) and Roller Tracks

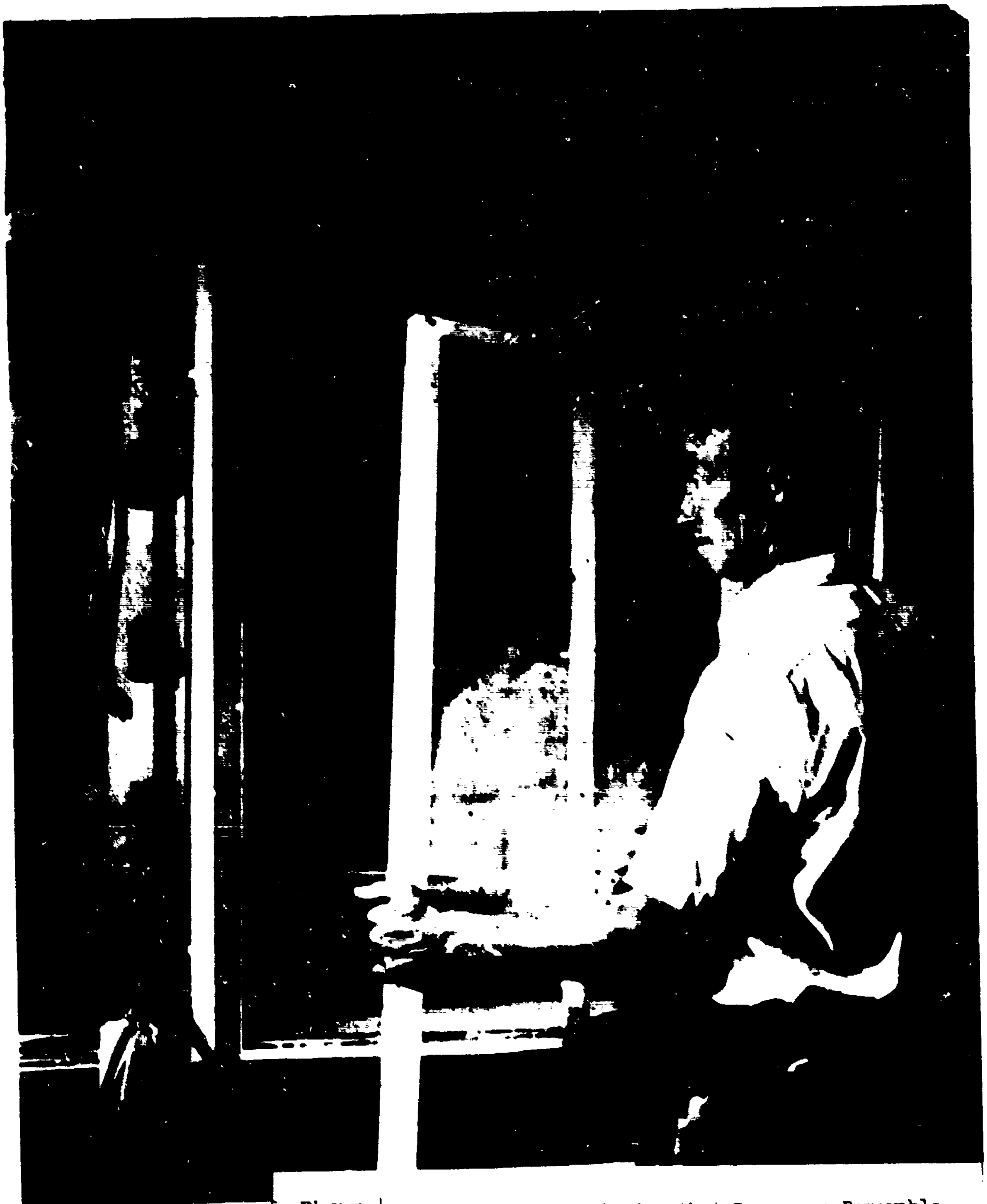


Figure 4   View of Hood Showing that Doors are Removable

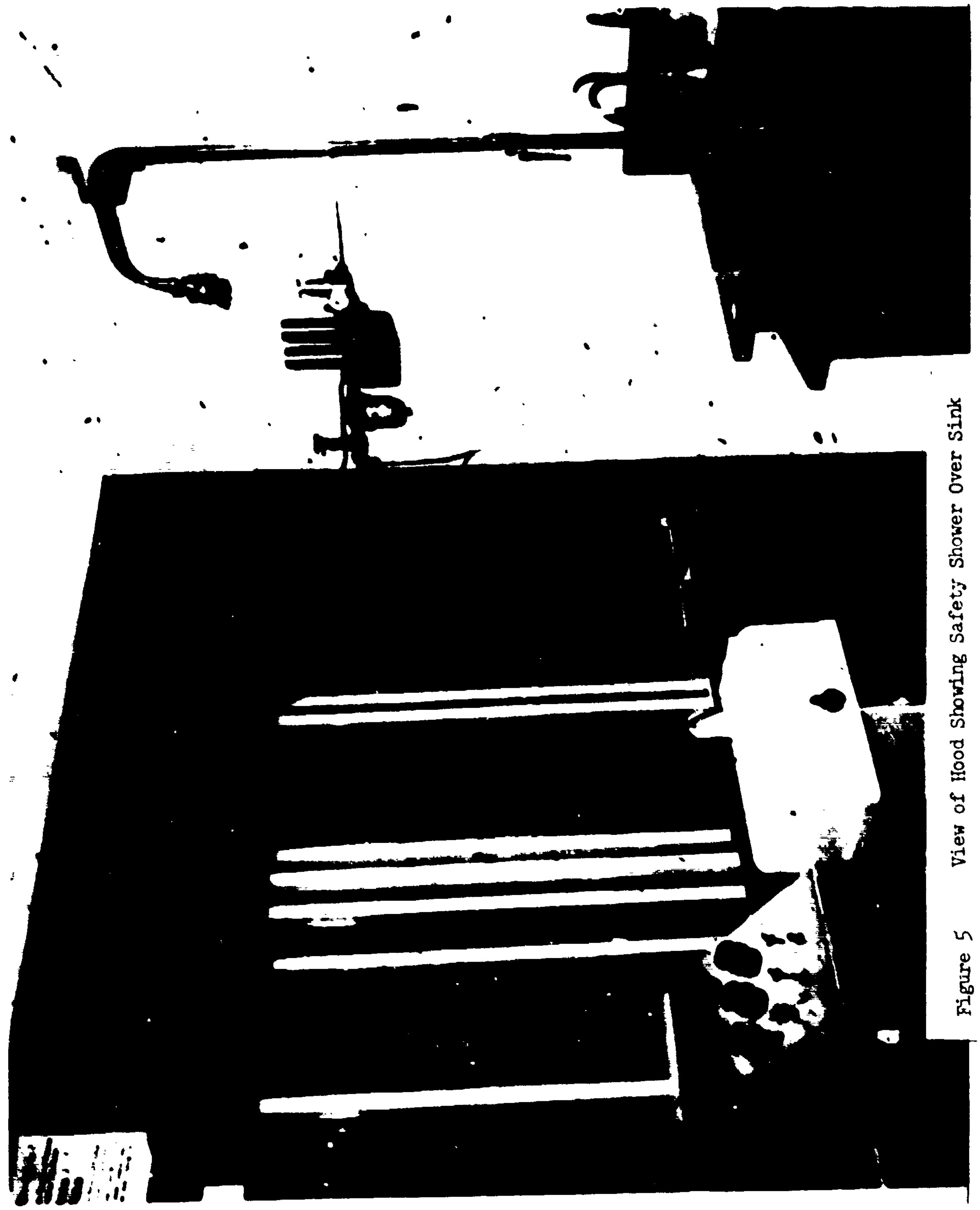


Figure 5 View of Hood Showing Safety Shower Over Sink

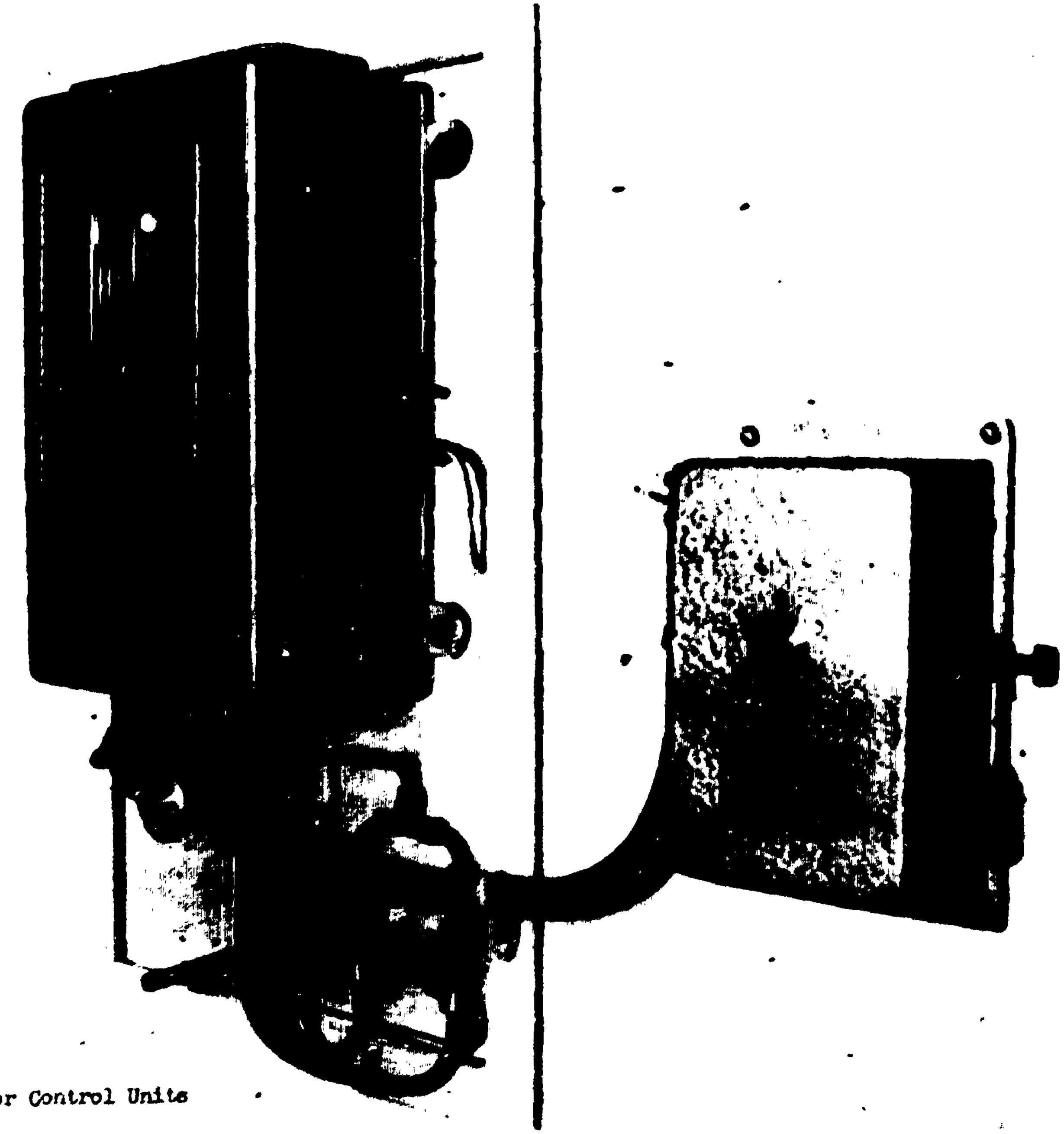


Figure 6

Gas Detector Control Units

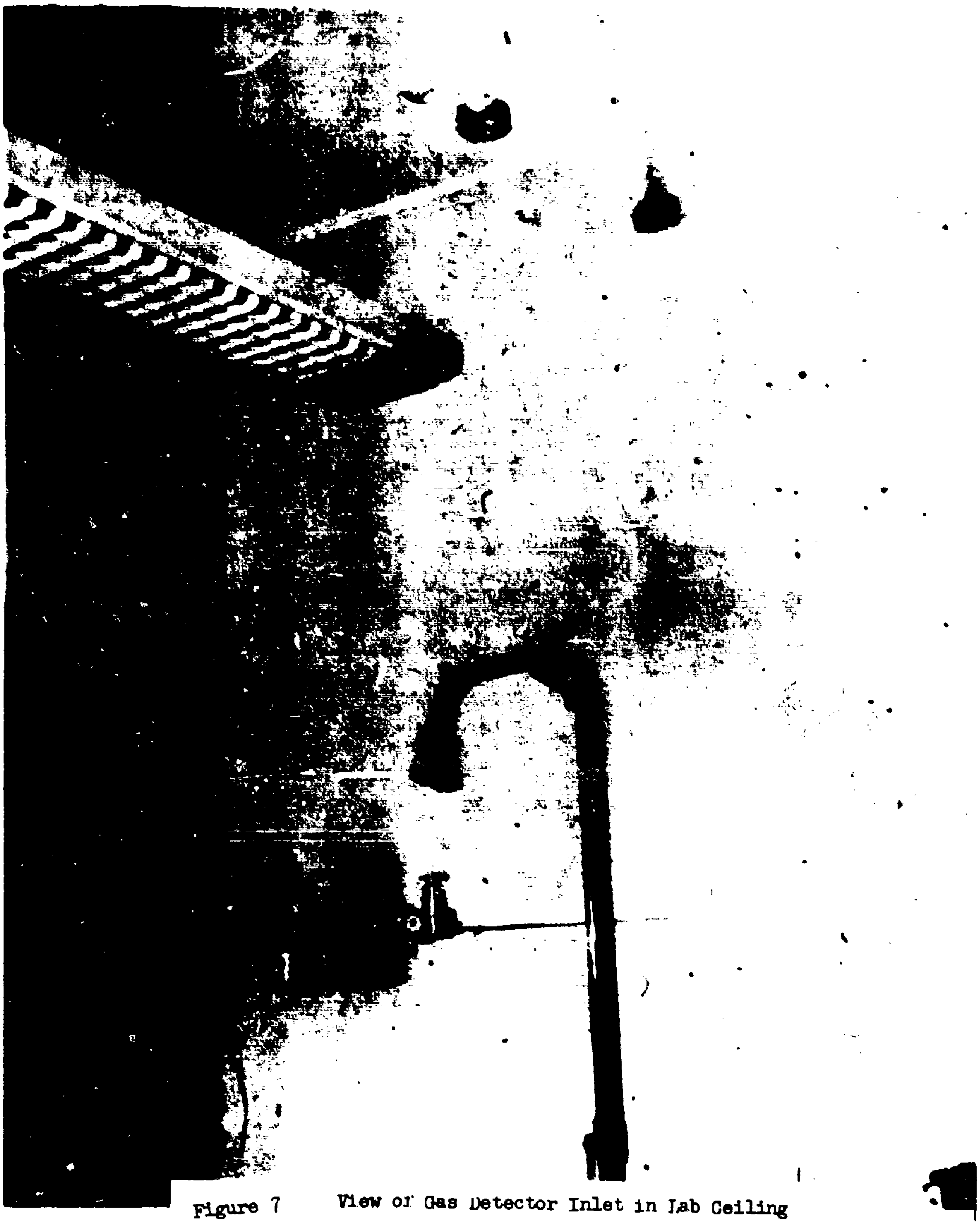


Figure 7 View of Gas Detector Inlet in Lab Ceiling

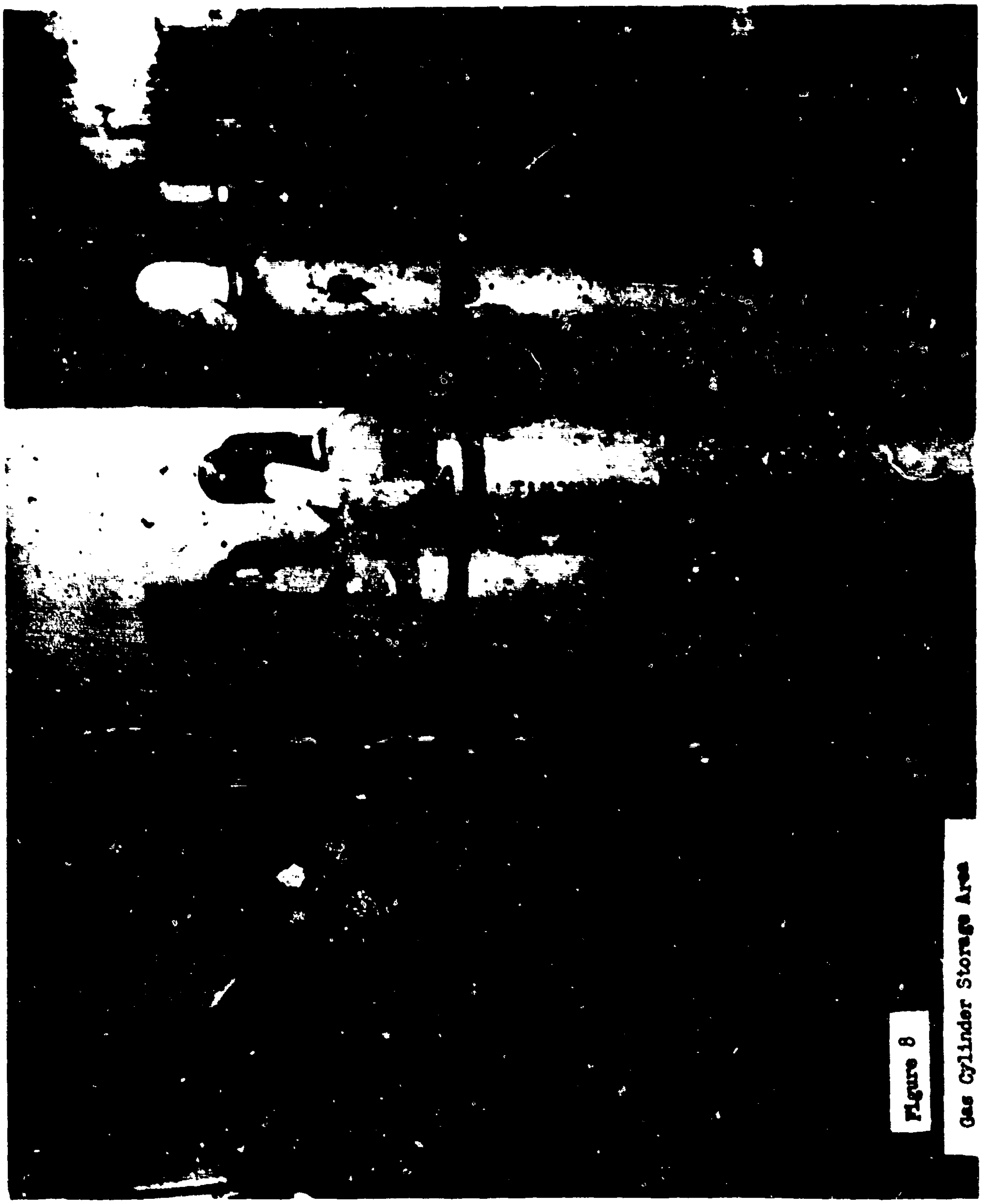


Figure 8

Gas Cylinder Storage Area

BLANK PAGE

APPLICATION OF THE PICATINNY LACED RE-ENFORCEMENT CONCEPT TO THE DESIGN OF AN INDUSTRIAL LABORATORY

by

H. Ph. Heubusch, Bell Aerosystems, Buffalo, N. Y.

INTRODUCTION

Bell Aerosystems is a Textron Company in their Defense Group specializing in a variety of aerospace products. Operations are centered in plants and laboratories in Arizona, Buffalo and Cleveland. The largest is in Buffalo where a main complex at Wheatfield, near Niagara Falls, is supported by a rocket test facility, the Bell Test Center, nearer Lake Ontario and an ACV test base on Lake Erie. In addition to rocket engines and ACVs Bell Aerosystems products include positive expulsion devices, V/STOLS, electromagnetic and electromechanical systems and aerospace devices such as the RMU. The Buffalo plant also produces,under subcontract to our sister company in Texas, parts for a variety of Bell Helicopters.

This diversity of products is designed, manufactured and built by a labor force including groups of chemists and chemical technicians who joined the company and set up laboratories to meet needs as they arose. In 1960 the expanding groups were united under a chief chemist and organized along conventional lines of inorganic, organic, analytical and physical chemistry with the various functions being performed slotted into these groups. The arrangement is shown in Figure 1. Note that certain of the functions, as their name impl ., are hazardous and facilities for these pose unique problems.

Figures 2 and 3 show the current location of laboratories which were developed over the years. Considering that approximately fifty men occupy these laboratories, it is readily apparent that they are small. Closer inspection of their names shows that the safety problem has been solved principally by putting the more hazardous operations in the Bell Test Center facility.

Since in many cases the same individuals move back and forth between laboratories in Wheatfield and Bell Test Center, a distance of approximately sixteen miles, it was proposed as a matter of

efficiency to construct one building in which as many laboratories as possible would be housed. Since the proposed building would be designed from the ground up with safety in mind, we had another compelling reason for adoption of our proposal. The safety factor also dictated the general configuration of the building; standard laboratories in one area, high hazard laboratories in another. Because of the changing pattern of aerospace work, the laboratories were to be of modular design for maximum versatility. Because other laboratories with which chemistry collaborates, metallurgical, research, manufacturing, etc., are located in Wheatfield, it was decided that the chemistry building would be constructed here rather than at Bell Test Center. In fact, only a small, recently completed, close support laboratory would remain at the Bell Test Center facility.

SITE SELECTION

An area of approximately 12,000 square feet with room for expansion was required for the chemistry building. With this statistic in mind, nine candidate sites were selected. They are shown as A-I in Figure 2. Next, a set of parameters was selected for rating the sites and each parameter was weighted in proportion to the others. One by one the sites were evaluated in terms of this relatively objective scale. It was then but a matter of arithmetic to determine which site was best over-all. The results of this exercise are shown in Figure 4. along with the details for each site when the blast hazard parameter was considered. Note that certain other sites were equivalent. Note that Site A which ranked first in the final analysis did not have a 100% score. In certain respects, e.g., centralized location, it was inferior to other sites.

BUILDING CONFIGURATION

Parallel with the site selection exercise the chemists participated in a number of brain storming sessions designed to come up with functional, modular laboratory designs. The output of these sessions is depicted in Figures 5 and 6 dealing with standard and high hazards laboratories respectively. As it turned out the two concepts shown for standard laboratories, an open wall vs an open center section, were selected and final design for the building consisted of detailing dimensions for the rooms and the relative numbers of each kind. In the case of the high hazard laboratories we selected the configuration featuring a common control room and direct access to a cubicle with a frangible wall at the far end. This appeared optimum for us since the degree of hazard involved in the type of work to be performed in a given cubicle varies from assignment to assignment and when conditions warrant a remote mode of operation is available.

Combining the above with the results of the site selection exercise produced the final configuration for the building shown in Figure 7. Note that hazardous operations quite properly face the unoccupied area. In fact, sufficient space is provided for a barrier should it develop that our neighbor should at some later date decide to occupy that area.

DESIGN OF HIGH HAZARDS LABORATORIES

Detail design of the high hazards laboratories began with the intention of utilizing the latest information available. The first task fell on the chemists who concluded that the structure should be capable of sustaining the effects of a blast equivalent to five pounds of TNT. This value was arrived at by reviewing past operations and concluding that the greatest hazard to be encountered would be associated with handling five gallons, maximum, of propellant. Applying the factors for density of

common mono and bipropellants this translated into approximately forty pounds of material. Following the current practice of using TNT equivalents of 10% for bipropellants and 15% for monopropellants we obtained a range of four to six pounds and settled on the value W equal to five for further calculations.

Through a fortunate circumstance, we learned of the work at Picatinny Arsenal on design of cubicle structures and appealed to them for guidance in our design task. Through a series of contacts the design data shown in Figure 8 were developed. Note that proper consideration has been given to location of our charge. The quantities of impulse, reflected pressure and leakage pressure were calculated as appropriate. The results it is recognized represent red lines which are subject to change as more is learned about the TNT equivalents of propellants.

More specifically, we computed the impulse loads on backwall, side walls and ceiling using the appropriate charts in the Manual (Reference 1). Impulse values for the observation port were determined from peak, normal reflected overpressure, Pr, assuming that the port would be stronger than the wall and movement of the wall would reduce strain on the port. This high strength was obtained by laminating six lites of tempored, polished glass plate, each 7/8 inches thick. Impulse loads on the blast door and access ports were likewise derived from Pr. With reference to the frangible walls, they are held in place by a set of pins which will shear should the wall be subjected to pressure. A blast within a cubicle will generate Pr, the pins will shear and the wall will fall out en masse. A blast from an adjacent cubicle may generate sufficient leakage pressure to shear the pins but a set of braces and the design of the frangible wall itself are such that the pressure will be withstood.

From the data shown and again with timely assistance from Picatinny Arsenal structural engineers engaged to design our

reenforced walls developed lacing patterns. It is interesting to note that their first attempts using conventional data gave a wall fifty per cent thicker and as they confessed not as strong as our final design. For a building our size this represents a difference of several hundred feet of floor space and a new margin of safety. The space saved helped make room for a set of ceramic and graphite laboratories for work on projects closely related to chemistry.

In keeping with what was being done regarding the walls and observation ports, several innovations were made for safer supply of services and control of air and water pollutants. In Figure 9 it is noted that special consideration is given normal waste, spills and flushing. Actually, all waste from the laboratories passes sensors en route to a retention tank where chemical treatment is performed automatically before the waste enters an ejection pit from which it exits to a sewer line. Spills are flushed into a dry well where chemical treatment can be applied before anything harmful can percolate into the soil. An automatic sprinkler system plus a manually operated deluge system are available for flushing. Rates of water supply are such as to preclude atmospheric pollution. Under normal circumstances, atmospheric pollution is avoided by filters in the exhaust systems and/or traps on experimental set ups as required.

The National Electrical Code was followed and all lighting in the high hazards laboratories is vapor proof (Class I, Division II, Group D). Switches and outlets are explosion proof (Class I, Division I, Group D). Electrical power is controllable from the control room.

Separate heating, ventillating and air conditioning units are installed in each high hazards laboratory. As already indicated each such laboratory also contains a hood. All electrical equipment is of the proper code and is operated from the control room.

Services, hot and cold water, gas, vacuum, nitrogen, electrical and instrumentation lines pass through specially designed sleeves from the control room. Access is at the ceiling, ten feet above the floor. Future requirements can be supplied through these sleeves within limits. If greater capacity is required, steel access ports are being included in the control room wall in a position such that barriers can be erected to prevent propagation of blasts.

TRAINING PROGRAM

Through the steps outlined above we believe we have a unique building. We recognize, of course, that though flexible it has limitations which must be understood for proper design of hazardous experiments. This pertains specifically to proper placement and sizing of a potential explosive. To assure proper use of the building we have already instituted a training program mandatory for the future occupants. The course content is shown in Figure 10. Timing is such that the course will be completed in October. We plan to take occupancy of the building a month or two later. When we do it will be with the conviction we have a modern facility which we will be able to fully utilize.

ACKNOWLEDGMENTS

In retrospect our building design was finalized in a relatively short time. The matter was expedited by generous cooperation of several men who deserve specific mention, viz., Mr. Ralph Baumgarten of the Parsons Company, Mr. Richard Rindner of Picatinny Arsenal, Mr. Norval Dobbs of Ammann and Whitney and Mr. Paul Gregoire, Plant Architect at Bell Aerosystems.

REFERENCES

1. Manual for Design of Protective Structures Used in Explosive Processing and Storage Facilities, Picatinny Arsenal, May 1968 (Review Copy)

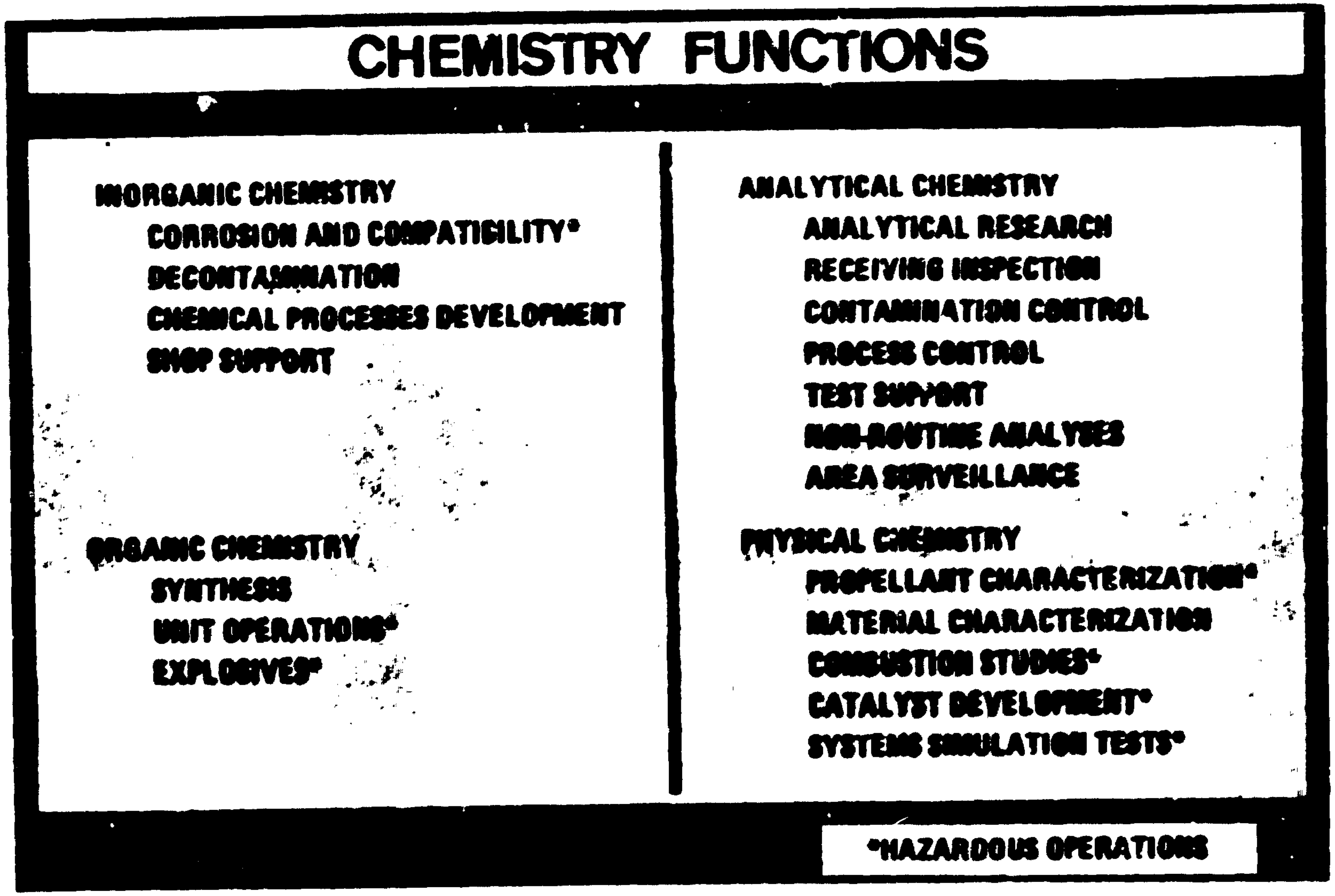

CHEMISTRY FUNCTIONS
INORGANIC CHEMISTRY
CORROSION AND COMPATIBILITY*
DECONTAMINATION
CHEMICAL PROCESSES DEVELOPMENT
SHOP SUPPORT
ORGANIC CHEMISTRY
SYNTHESIS
UNIT OPERATIONS*
EXPLOSIVES*
ANALYTICAL CHEMISTRY
ANALYTICAL RESEARCH
RECEIVING INSPECTION
CONTAMINATION CONTROL
PROCESS CONTROL
TEST SUPPORT
NON-ROUTINE ANALYSES
AREA SURVEILLANCE
PHYSICAL CHEMISTRY
PROPELLANT CHARACTERIZATION*
MATERIAL CHARACTERIZATION
COMBUSTION STUDIES*
CATALYST DEVELOPMENT*
SYSTEMS SIMULATION TESTS*
*HAZARDOUS OPERATIONS

Figure 1

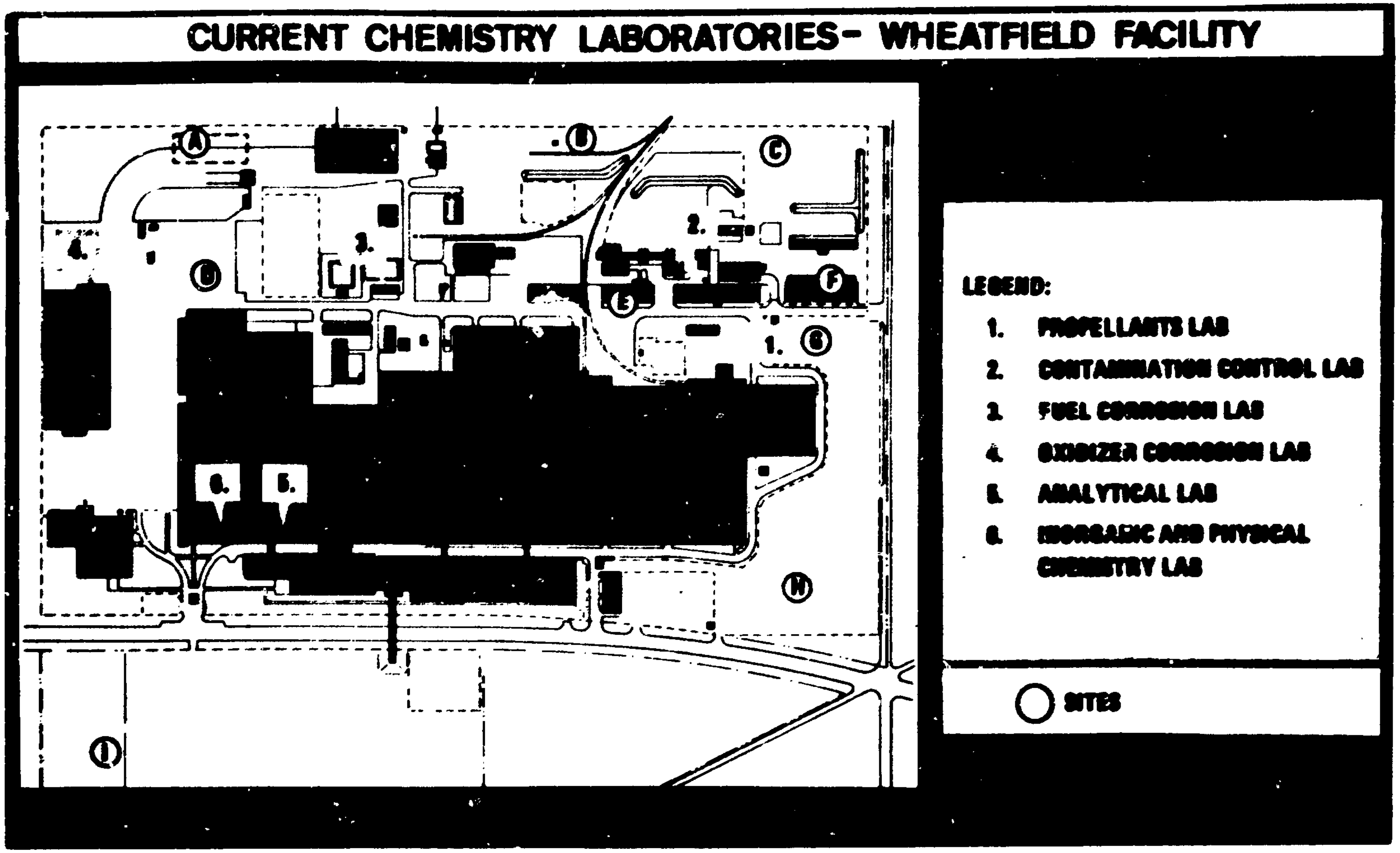

CURRENT CHEMISTRY LABORATORIES- WHEATFIELD FACILITY
LEGEND:
1. PROPELLANTS LAB
2. CONTAMINATION CONTROL LAB
3. FUEL CORROSION LAB
4. OXIDIZER CORROSION LAB
5. ANALYTICAL LAB
6. INORGANIC AND PHYSICAL CHEMISTRY LAB
SITES

Figure 2

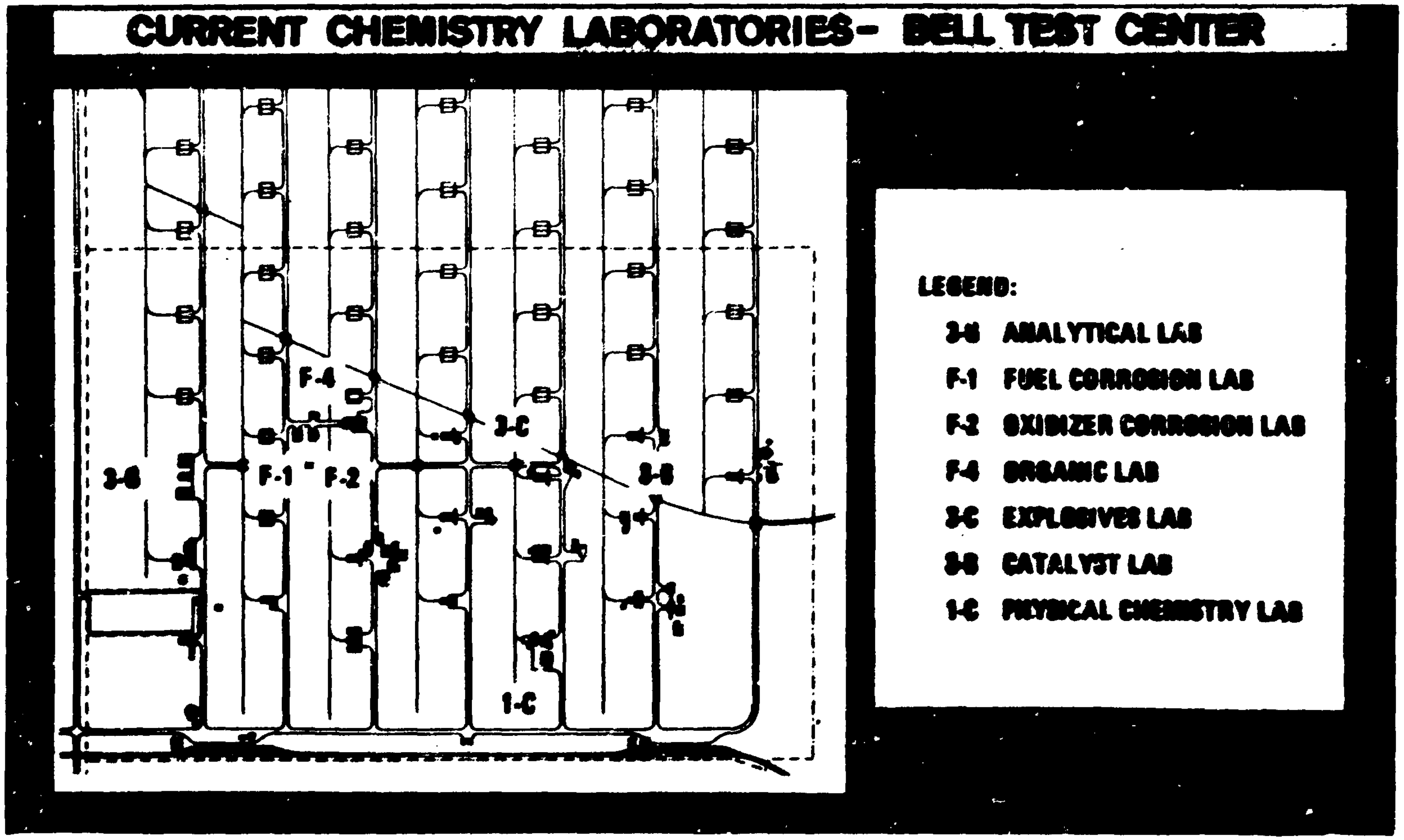

CURRENT CHEMISTRY LABORATORIES- BELL TEST CENTER
F-4
3-C
F-1
F-2
1-C
LEGEND:
ANALYTICAL LAB
F-1 FUEL CORROSION LAB
F-2 OXIDIZER CORROSION LAB
F-4 ORGANIC LAB
3-C EXPLOSIVES LAB
CATALYST LAB
1-C PHYSICAL CHEMISTRY LAB

Figure 3

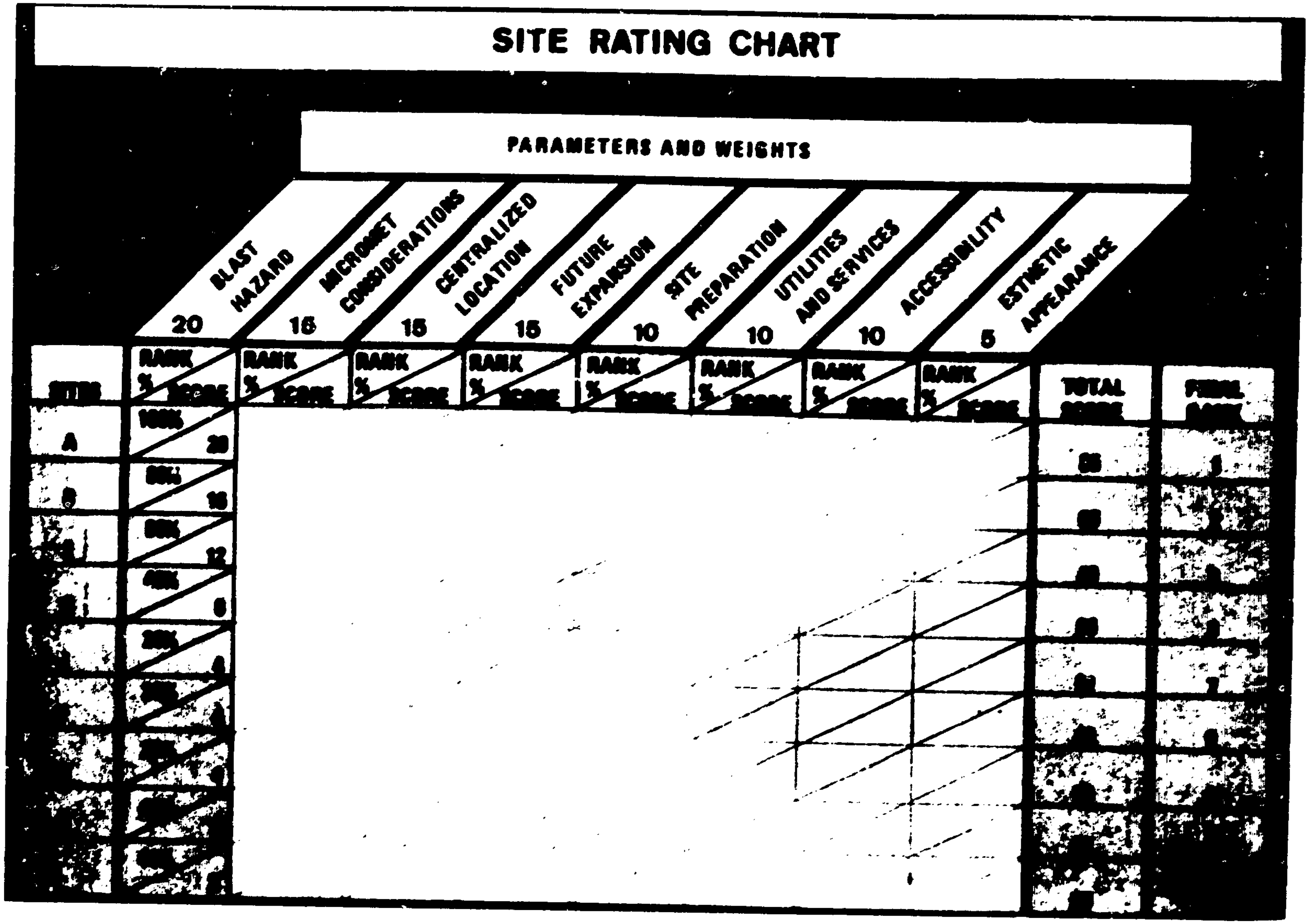

SITE RATING CHART
PARAMETERS AND WEIGHTS
BLAST HAZARD
20
MICROMET CONSIDERATIONS
15
CENTRALIZED LOCATION
15
FUTURE EXPANSION
15
SITE PREPARATION
10
UTILITIES AND SERVICES
10
ACCESSIBILITY
10
ESTHETIC APPEARANCE
5
RANK
%
SCORE
TOTAL SCORE
SITES
A
100%
20
16
12
8

Figure 4

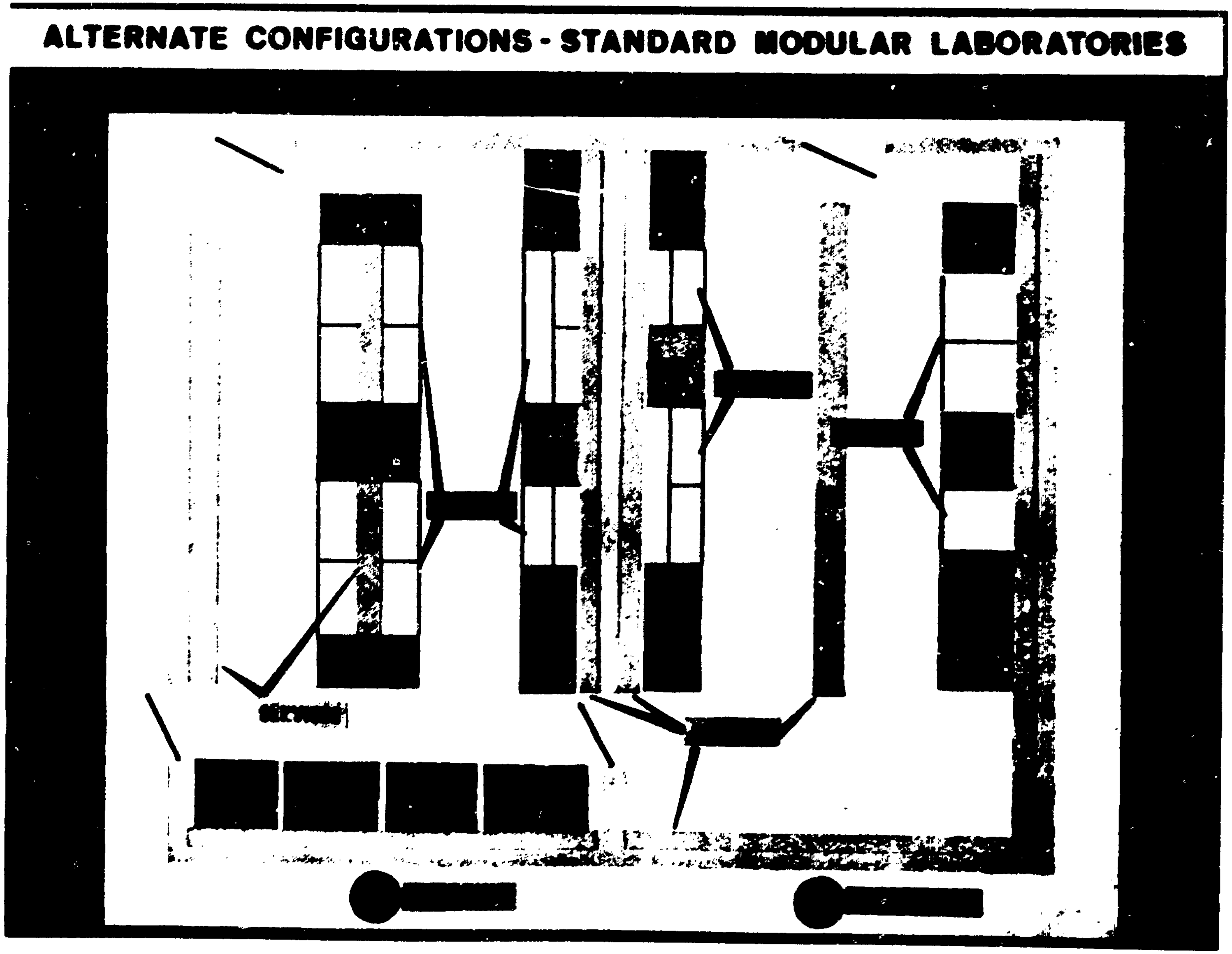

ALTERNATE CONFIGURATIONS - STANDARD MODULAR LABORATORIES

Figure 5

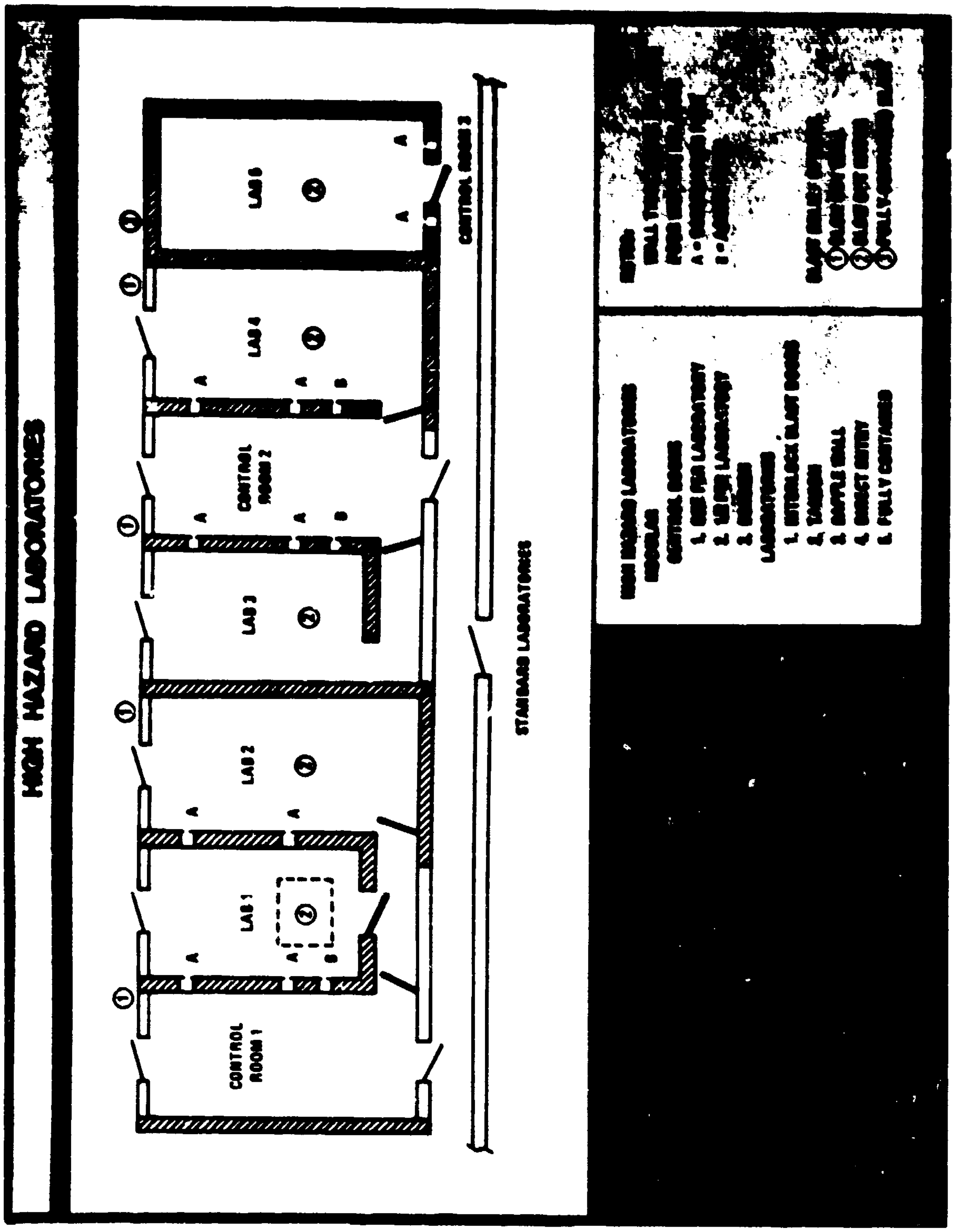

HIGH HAZARD LABORATORIES
CONTROL ROOM 1
LAB 1
LAB 2
LAB 3
CONTROL ROOM 2
LAB 4
STANDARD LABORATORIES

Figure 6

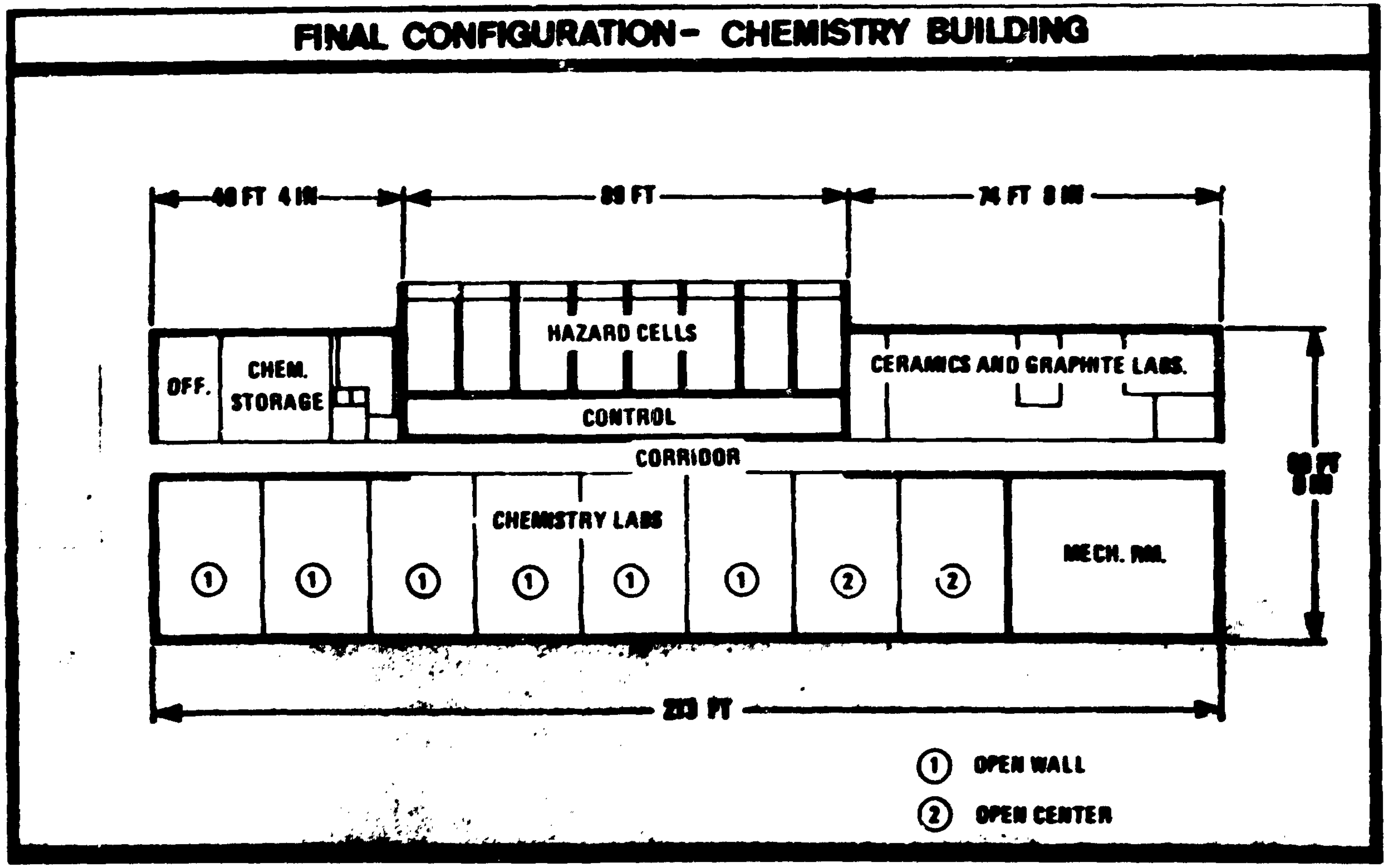
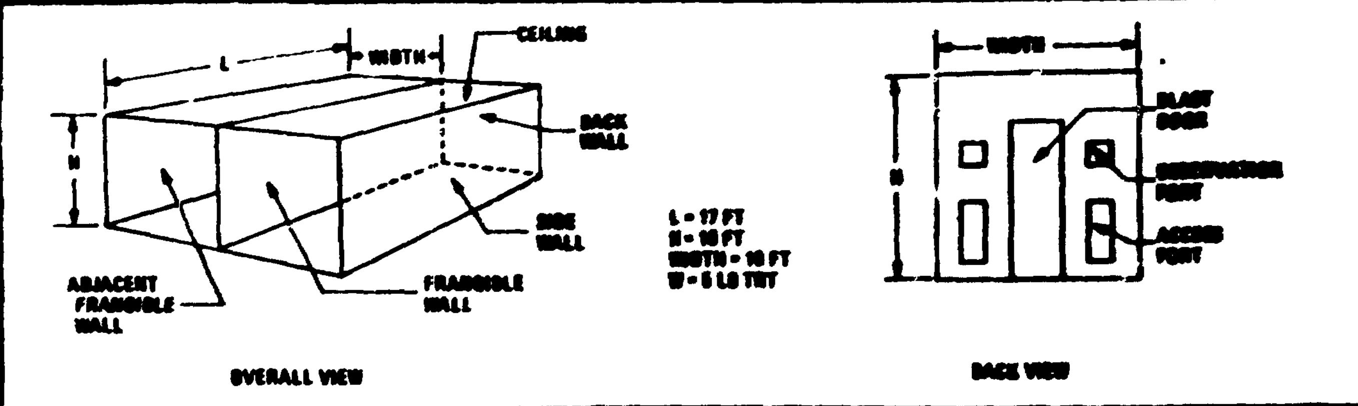

FINAL CONFIGURATION- CHEMISTRY BUILDING
HAZARD CELLS
CONTROL
OFF.
CHEM. STORAGE
CERAMICS AND GRAPHITE LABS.
CORRIDOR
CHEMISTRY LABS
MECH. RM.
74 FT 8 IN
① OPEN WALL
② OPEN CENTER

Figure 7

BLAST DESIGN CRITERIA



	CHARGE LOCATION	TARGET	PARAMETER	RESULT	MANUAL REFERENCE
1.	1.5 FT BEHIND TARGET	OBSERVATION PORT	i_r, psi-ms	725	FIG. 4-5
2.	1.5 FT BEHIND TARGET	ACCESS PORT	i_r, psi-ms	725	FIG. 4-5
3.	1.5 FT FROM SIDE WALL 5.0 FT FROM FLOOR 40° ANGLE TO NEAR EDGE TARGET	BLAST DOOR	i_r, psi-ms	246	FIG. 4-5 FIG. 4-8
4.	1.5 FT FROM SIDE WALL 5.0 FT FROM FLOOR 1.5 FT FROM TARGET	BACK WALL	i_r, psi-ms	284	FIG. 4-60 FIG. 4-61 FIG. 4-62
5.	1.5 FT FROM SIDE WALL 5.0 FT FROM TARGET	SIDE WALL	i_r, psi-ms	280	FIG. 4-46, 48 FIG. 4-51, 53
6.	1.5 FT BEHIND TARGET	FRANGIBLE WALL	P_r, psi	20	FIG. 4-5
7.	1.5 FT FROM SIDE WALL 1.5 FT FROM BACK WALL 5.3 FT FROM TARGET	CEILING	i_r, psi-ms	246	FIG. 4-43 THROUGH FIG. 4-53
8.	1.5 FT FROM SIDE WALL 1.5 FT FROM FRANGIBLE WALL 8.0 FT FROM TARGET	ADJACENT FRANGIBLE WALL	P_{so}, psi	80	FIG. 4-63

Figure 8

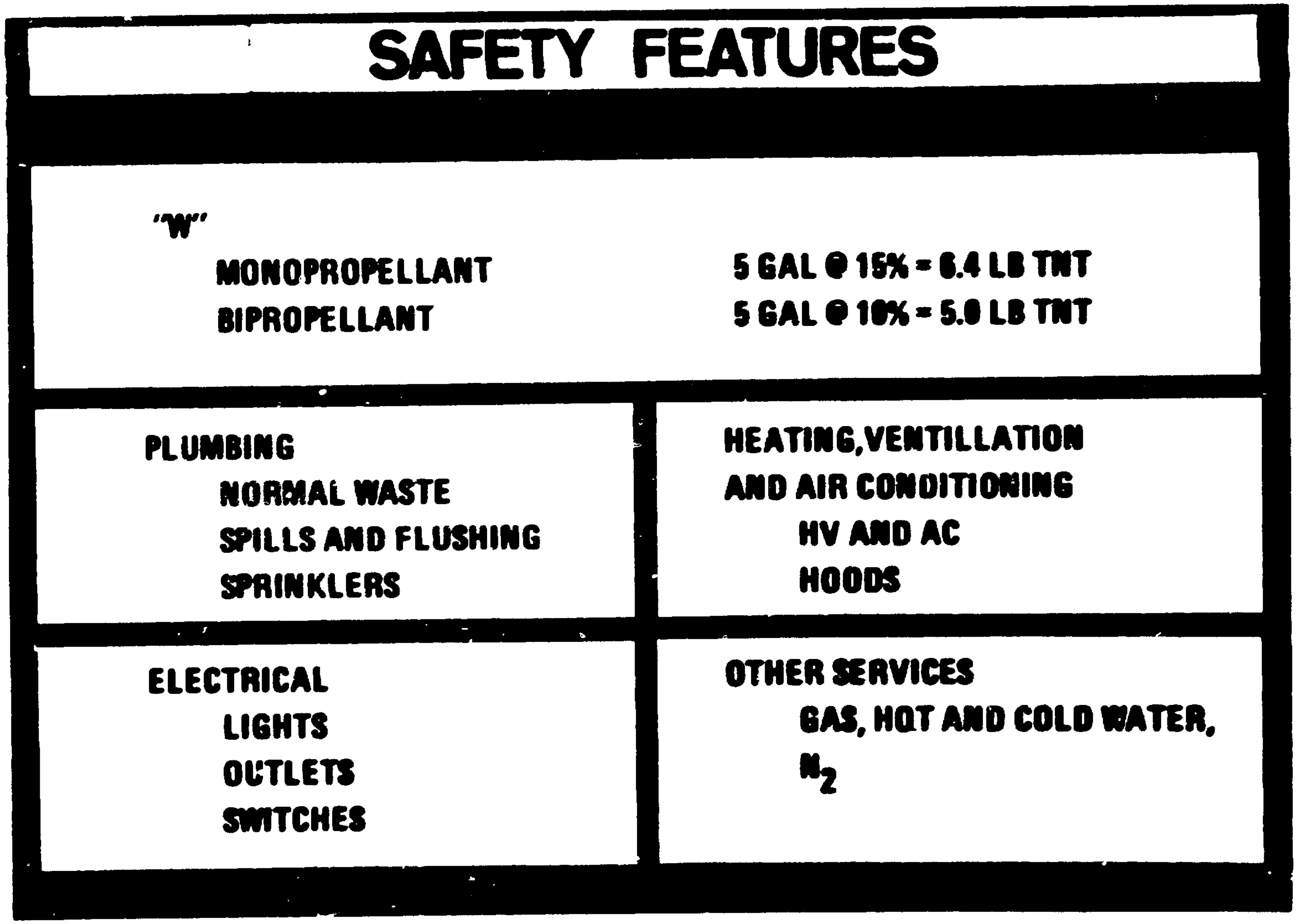

SAFETY FEATURES
"W"
MONOPROPELLANT
BIPROPELLANT
5 GAL @ 15% = 6.4 LB TNT
5 GAL @ 10% = 5.0 LB TNT
PLUMBING
NORMAL WASTE
SPILLS AND FLUSHING
SPRINKLERS
HEATING, VENTILLATION
AND AIR CONDITIONING
HV AND AC
HOODS
ELECTRICAL
LIGHTS
OUTLETS
SWITCHES
OTHER SERVICES
GAS, HOT AND COLD WATER,
N2

Figure 9

TRAINING PROGRAM

1. DEFINITIONS
2. METHOD OF CALCULATING AVERAGE CLOSE IN BLAST LOADS
3. UNCONFINED SURFACE BLASTS
4. LEAKAGE PRESSURE
5. FREE AIR BLAST
6. CLOSE IN BLAST LOADS
   - BACK WALL
   - SIDEWALL
   - CEILING
7. VARIATION IN IMPULSE WITH NUMBER OF REFLECTING SURFACES
8. METHOD OF CALCULATING REFLECTION EFFECTS AT A POINT
9. CONFINED BLAST

Figure 10

USE OF OPERATIONAL SHIELDS

Royal Kahler
MASON & HANGER - SILAS MASON CO., INC.
CORNHUSKER ARMY AMMUNITION PLANT
Grand Island, Nebraska

Use of operational shields, particularly with explosives and explosives loaded components, falls into three general categories as:

a. Protection for the operator concerned.

b. Protection for other personnel adjacent to, but not necessarily directly connected with, the operation requiring the shield.

c. Protection for nearby explosives and components against propagation and communication of an incident at a protected location.

Obviously the physical characteristics of any operational shield should be such that it will perform its function satisfactorily in the event of an unfortunate accident. Determination of the suitability of the shield for its intended purpose should naturally be based on facts and not left to guess or chance. Past experience can always be utilized as a reliable guide; lacking this experience, it follows that experimentation and tests are in order.

Fundamental design characteristics are important "first steps". Thorough test programs and competent as well as honest evaluation of test results too, are essential since true knowledge has never been established on half-truths. Economy of design and of fabrication or installation, although related factors, are of secondary importance when reliable protective shields are intended. Half-way measures are not good enough when the "chips are down" and things start flying. There are times, however, when protection in its full sense cannot be achieved, and the safeguards installed can only afford a degree of protection. In these cases, it is essential that the limitations of the shields be recognized. Over-estimating the protective characteristics of operational shields based on "hope" can be dangerous.

Within practical limitations, it is next to impossible to design a totally enclosed shield to retain the explosive effects developed by the detonation of say a 90mm H.E. loaded projectile. There is far too much gas and too many high velocity fragments to be effectively imprisoned in a small "box". Venting the gases quickly to the atmosphere in the direction having the least number of targets is the means most often employed to control the effects of an accidental explosion. Retaining a majority of the missiles within the barrier and restraining or controlling the flight pattern of the remainder are goals not easily attained.

In an eagerness to design safe working enclosures for explosives processing secondary exterior hazards are often overlooked. Sometimes the things we build for protection inadvertently include the very same hazards we try to protect against. An operational shield for relatively small explosives charges, i.e., one or two pounds, frequently employs bolts and nuts to hold its steel plates in position. The plates themselves are sufficiently strong to withstand penetration of the missiles produced within. Their flexing and bulging under the impact of gas pressures however, often tear loose the nuts used to hold the shield together and propel them with about the same lethal effects as the missiles from the explosives-filled item.

The precise origin of the missiles that causes injury or fatality in these cases is of little concern to the principal. To guard against this hazard, welded corners and joints are generally superior to those secured with bolts and nuts, particularly if the size of the bolts is calculated on the basis of pure mechanical shocks and stress. (Reference enclosures 1, 2 and 3)

Also, unless care is exercised to guard against it, overturning of operational shields during an explosion of the larger quantities or components can be a real threat. When this happens, it is not unrealistic to believe that, in overturning, it may cause more casualties than if it was not there. It is obviously essential therefore, to anchor the shield securely. More important than heretofore realized, the employment of buttress angles (knee braces in reverse) at strategic points to reduce the overturning movement to controllable levels is warranted.

Like the "use" categories for operational shields, the fundamental design and installation characteristics to be included also fall into three general groupings as:

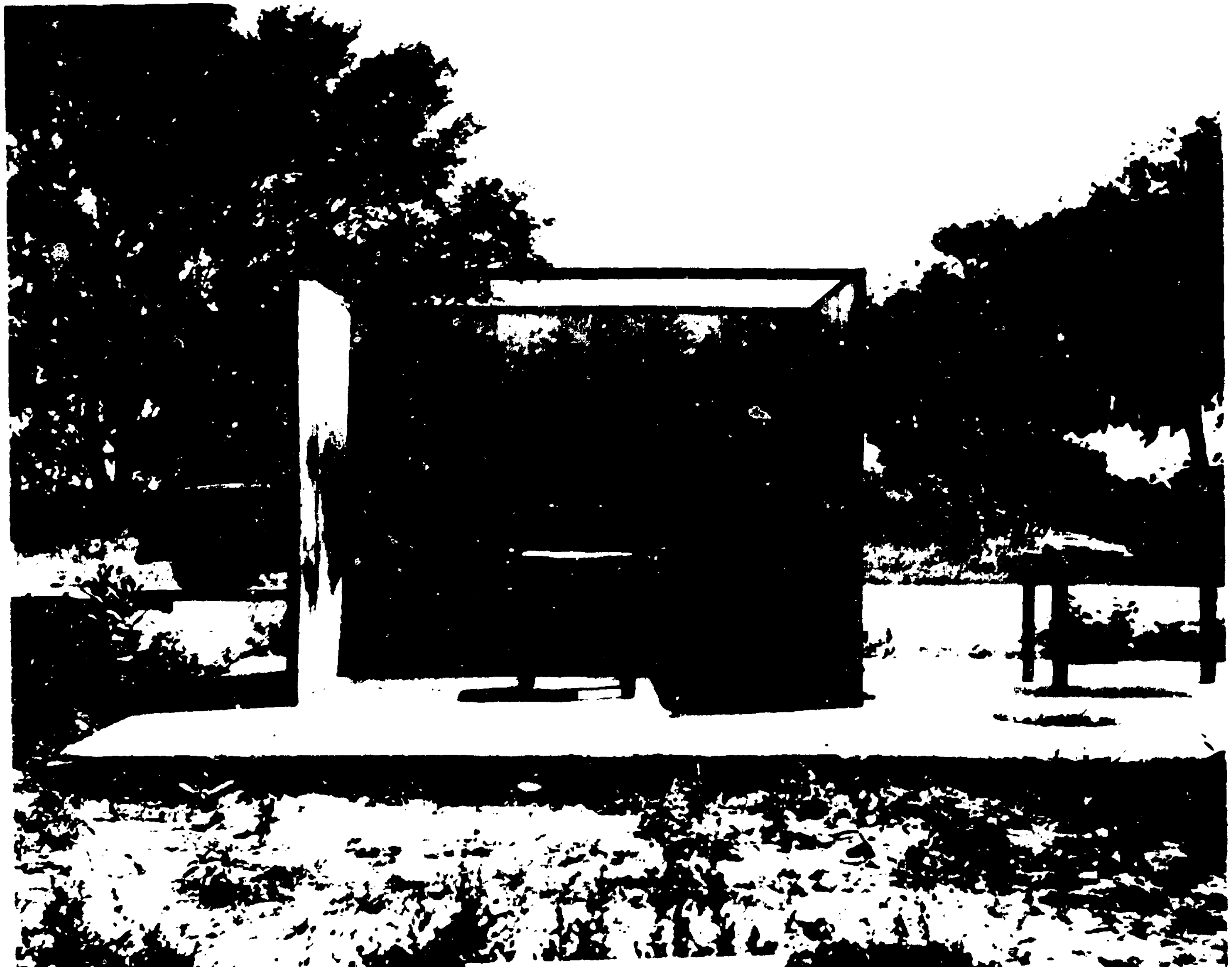
a. Selection of materials and the fabrication of these materials in a manner known to be capable of defeating the explosive forces generated, without the introduction of additional hazards.

b. Installation of the shield in a manner to insure stability during an explosion.

c. Proper orientation of the barrier with respect to nearby operators and other targets in a direction known to expose the fewest number of targets.

Enclosure no. 4 depicts an Operational Shield Test Report for XM41 Individual Mine Test. Enclosures no. 5 and 6 show a Building B-10 Laboratory Incident at CAAP involving an XM41E1 mine during quantitative analysis. The shielding installed in the laboratory was based on the acceptability of the shielding tested as reflected in enclosure no. 4. As shown in enclosures no. 5 and 6, the explosive force was well contained by the shielding and the operator sustained only minor injuries.

Inclosure 1



Inclosure 2

Inclosure 3

OPERATIONAL SHIELD TEST REPORT
FOR
XM41 INDIVIDUAL MINE TEST

by

R. E. Donaldson and R. J. Kahler
Mason & Hanger-Silas Mason Co., Inc.
Cornhusker Army Ammunition Plant
Grand Island, Nebraska

Introduction

Mason & Hanger-Silas Mason Co., Inc., at the Grand Island, Nebraska, Cornhusker Army Ammunition Plant has been producing the XM45, Anti-Intrusion Mine, with prime components of lead azide and RDX.

In preparing for initial production of the XM41, Anti-Personnel Mine, involving greater amounts of these same components, a test was made to determine the adequacy of a protective booth currently in use after it was modified with a 1/2" steel personnel shield designed specifically to protect the lower extremeties of the body and a 1/2" steel shield designed to fortify the lower portion of the plastic operational shield.

Each production operator is equipped with a protective booth. The conveyor belt, carrying "boats," each transporting one mine, runs through the booth. Steel and plastic protective shields are between the operator and the mine assembly, situated so that only the operator's hands and forearms are exposed.

Abstract

A test was made to determine the adequacy of an operational shield designed for use with one (1) XM41 Anti-Personnel Mine, incorporating a mixture of lead azide, RDX, and Cab-o-sil. This test was conducted due to absence of reliable data per paragraph 2622 (b) of AMCR 385-224.

A mine loading procedure was simulated at the burning grounds. An XM41 charge plus 25% safety factor was detonated by a #8 blasting cap. The charge was detonated from a firing bunker. The resulting explosion caused no structural damage to any portion of the protective booth.

Test Set-Up

A replica of a protective booth currently in use, with the addition of a steel plate to reinforce the lower portion of the Plex-I-Glass, was situated at the burning area.

Inclosure 4

The three-sided booth shown in figures 1 and 2 was constructed of steel on all three sides with a Plex-I-Glass, clear, 1" thick, type G, face and upper body shield, mounted in place with 2" by 1/2" angle iron. The Plex-I-Glass shield is shaped with armhole allowances for manipulation of boats carrying mines on the conveyor belt, which runs through the booth.

A metal boat containing one (1) XM41 charge plus 25% safety factor was positioned on a work shelf adjacent to the Plex-I-Glass shield. For this test freon wet RDX and lead azide were used without the addition of Cab-o-sil. Reference figure 3 which shows the conveyor running through the booth with the explosives container on the work shelf.

Figure 4 shows the position of the explosives container adjacent to the Plex-I-Glass shield and steel reinforcement.

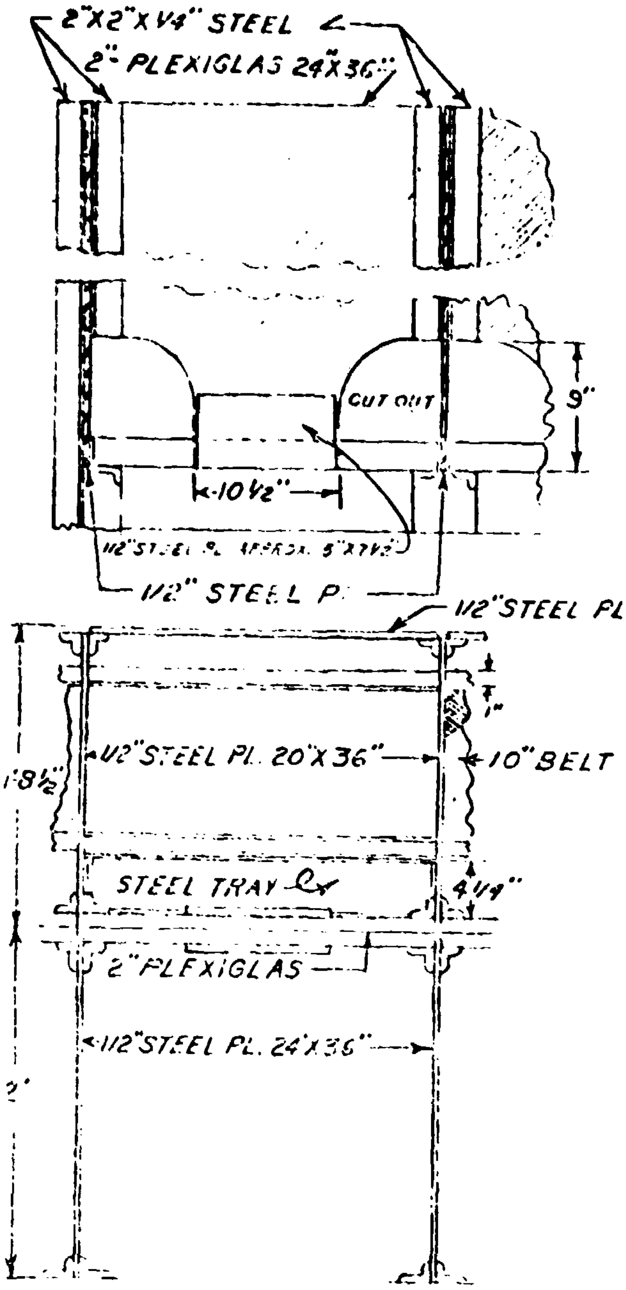
Test Results

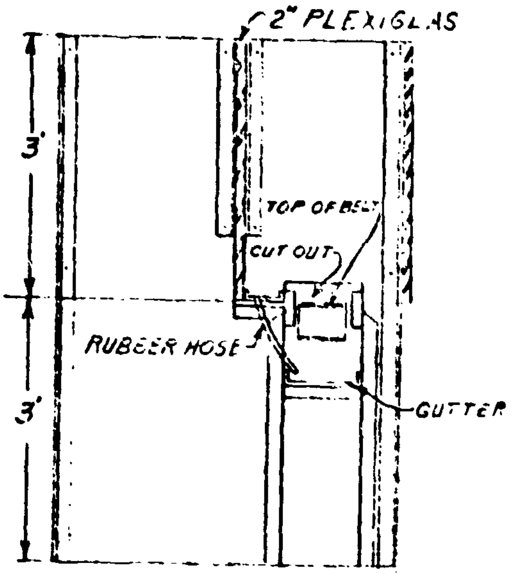
The explosive force was well contained by the shielding. A side view of the total booth construction after detonation is shown in figure 5. It may be noted in this picture and in figures 6 and 7 that the conveyor belt and work shelf were slightly depressed by the explosion.

The Plex-I-Glass shield remained intact having sustained a fissure approximately 8" long.

Conclusion

The Plex-I-Glass shield with steel reinforcement proved to be adequate for one (1) XM41 charge plus 25% safety factor.





Note: For the individual mine test, a single 1" plexiglass shield was used.

Figure 1
TYPICAL BOOTH XM41E1

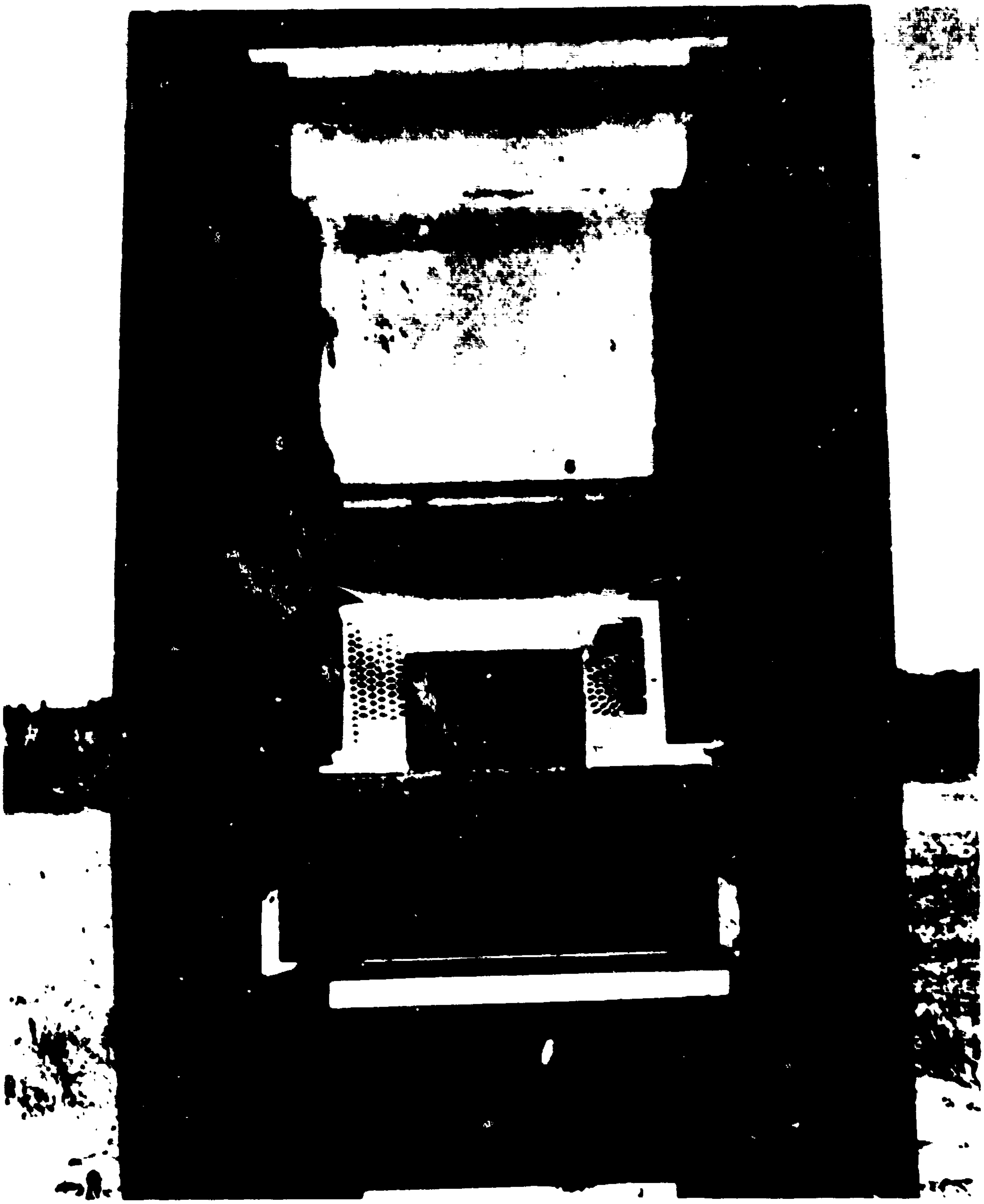


Figure 2

Figure 3

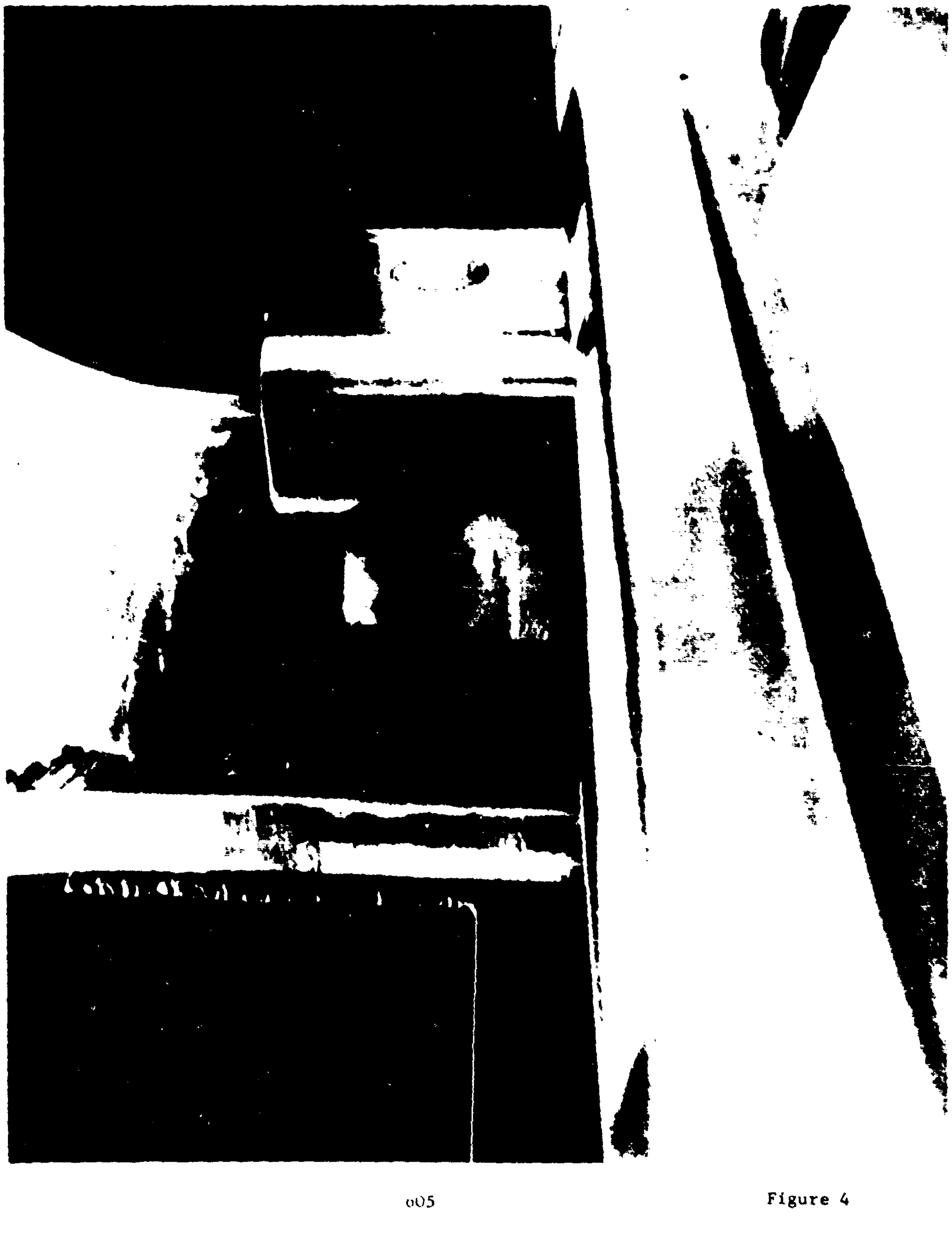
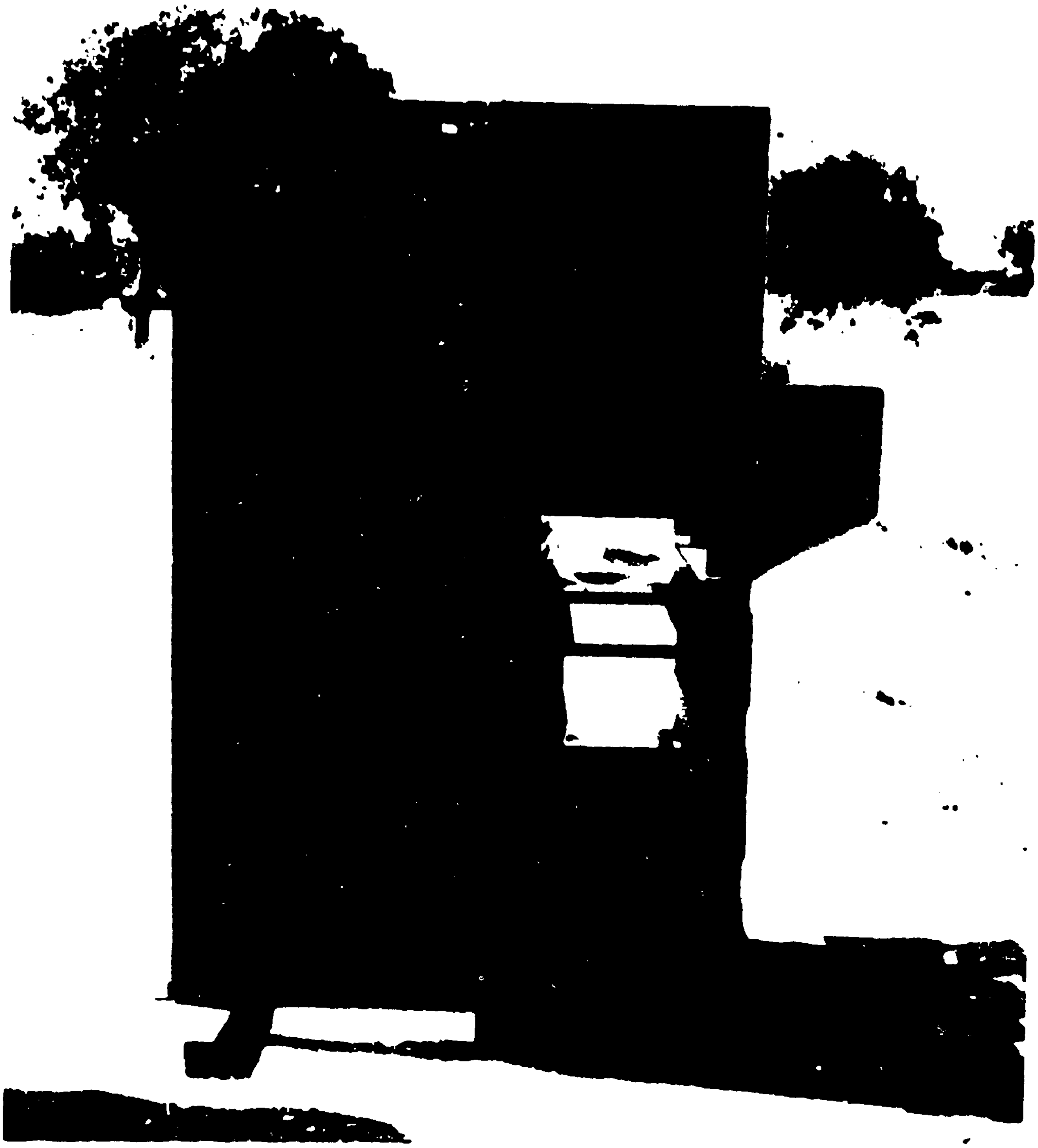


Figure 4

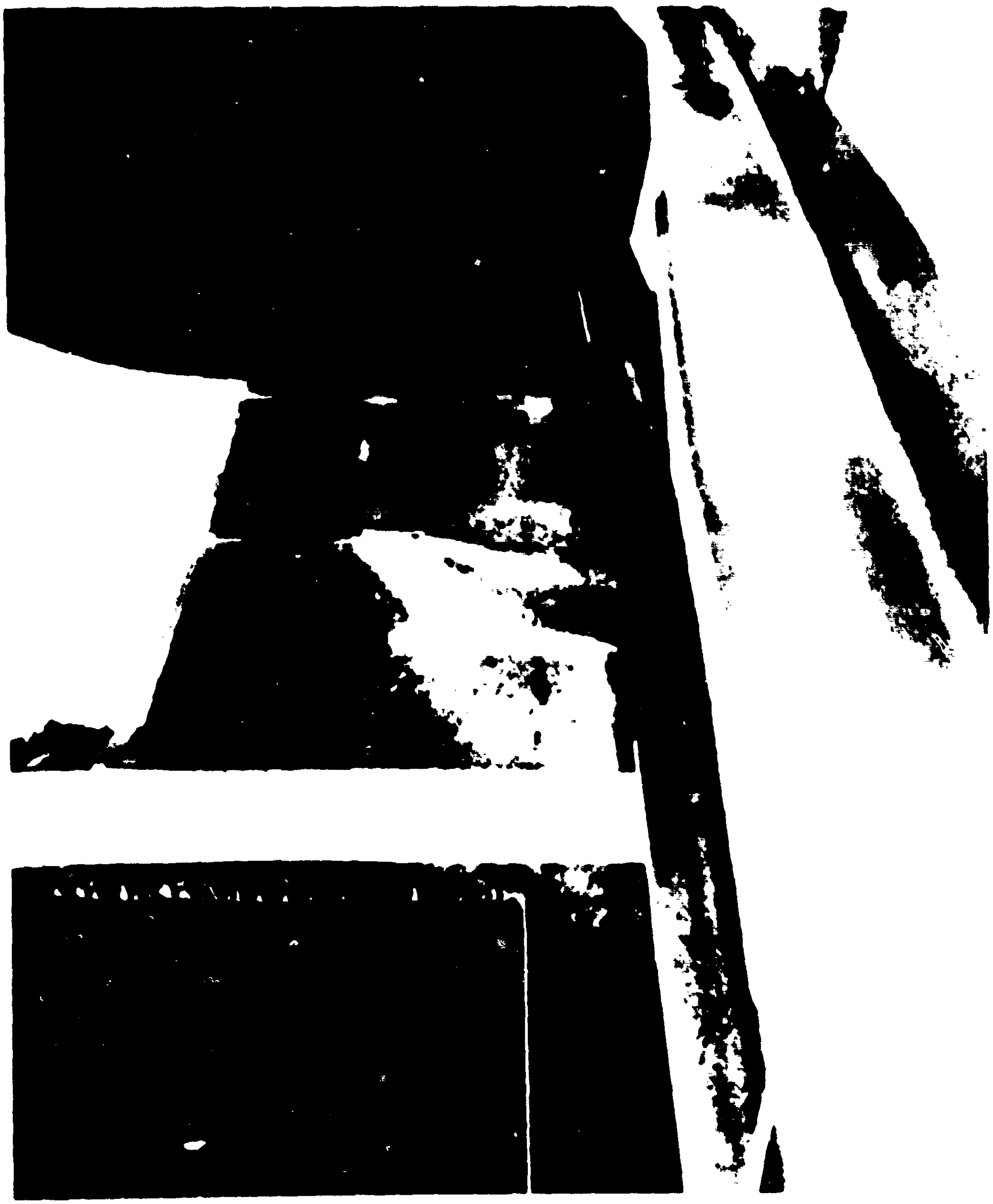


606

Figure 5

607

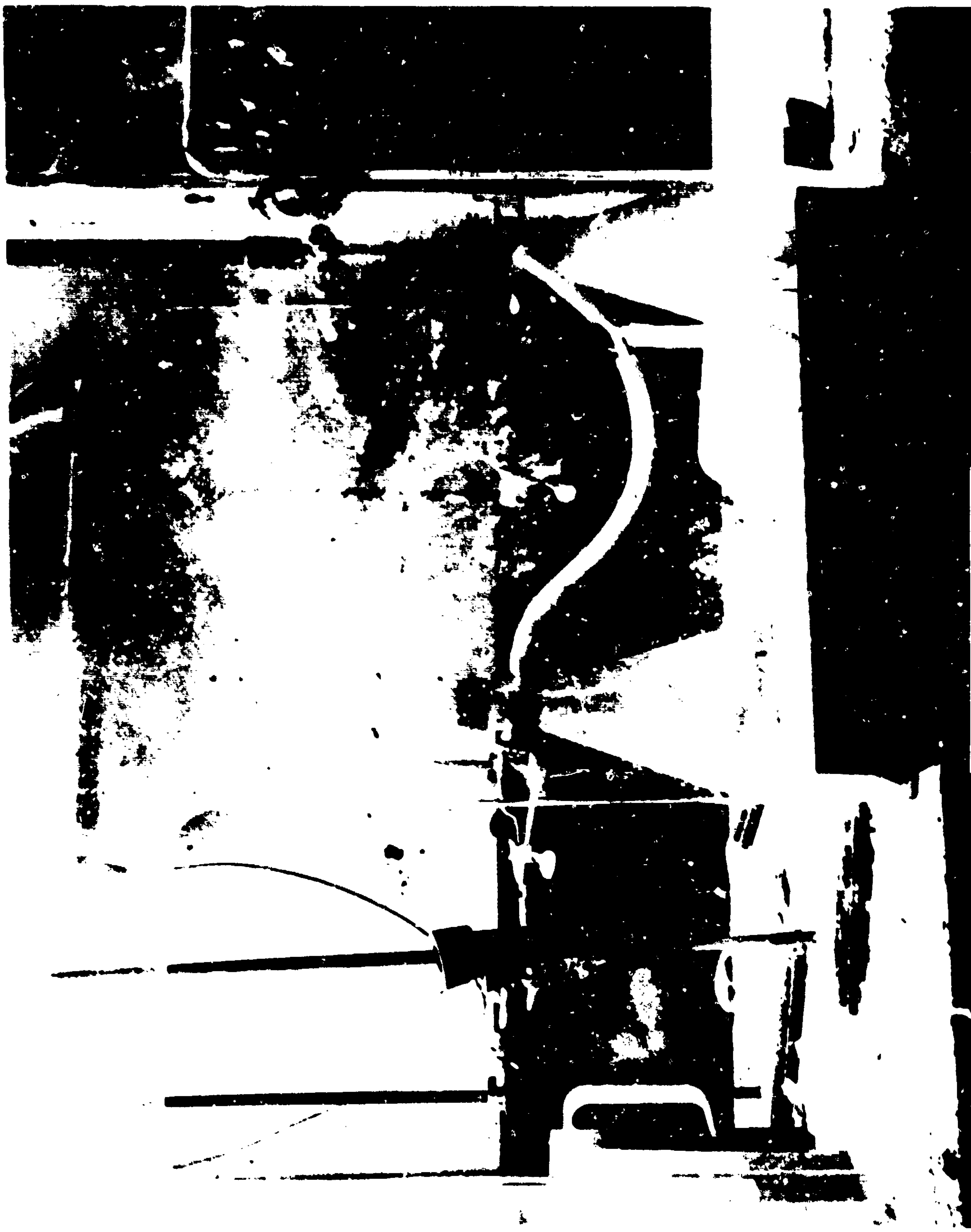
Figur



008

Figure 7

Inclosure 5



Inclosure 6

DESIGN OF FACILITY FOR SAFE STORAGE OF ARMED AERIAL MINES

by

Stanley Wachtell
Picatinny Arsenal
Dover, N. J.

Gravel

In manufacturing the Mine, mines are maintained in the unarmed condition throughout the manufacturing process and during storage. However, control of production requires that large numbers of mines be armed and stored in controlled temperature and humidity chambers for a long time before testing. During this period, the armed mines are periodically removed from the chamber by an explosive operator and tested for functioning. The operator removes the mine by catching a loop of cord, previously attached before arming, in a hook at the end of a long pole. To do this, the operator must enter the controlled conditioning chamber. The protective gear worn by the operator is adequate to protect him from injury should the one mine at the end of thepole detonate. However, if the mine should drop and detonation occur the explosion could propagate other mines stored in the chamber. To protect the operator, the mandatory storage criteria was tentatively set at two foot separation between armed mines while in the conditioning chamber.

The purpose of this program was to study the propagation characteristics of XM41 Mines and to design a storage system which would increase the storage capacity of the controlled temperature humidity chamber and reduce the hazard to the operator.

The general approach used in this test program was to establish whether -- by adequate barricade design -- it was possible to materially increase the capacity of the conditioning chamber. This storage chamber had a limit of 64 units imposed by the two-foot separation requirement.

To develop the information for designing increased storage capcity of conditioning chambers it was first necessary to establish the factors responsible for propagation of the mines.

A series of 17 tests were run to demonstrate what these propagation characteristics were. These are shown in Figures1 to 6. (See Reference 1)

The results of these tests showed that we could place mines at the center of an 8" pipe and that no propagation would occur between pipes through blast. Prevention of fragments was still necessary.

A test storage rack was designed with a wire mesh bottom to allow for air circulation and for maximum economy in handling and space. This is shown in (Figure 7). Two mines were placed in upper rack. One propagation occurred in lower right.

Next test was duplicate of previous one but with a sheet of poly foam to absorb fragments which might be reflected off bottom plate (Figure 8) - Five additional tests showed no propagation.

Five tests were then run with 2 mines donor in lower step (Figure 9). Propagation only occurred on last test at which time the test rack had been badly distorted and fragments could have traveled to acceptor horizontally.

Final storage rack was designed (Figure 10) and built. This section was about 5 feet deep and 8 feet long. Test set up shown in Figure 11. Two donors in center with 8 surrounding pipes loaded - No propagation.

Next test with one mine protruding slightly as shown in Figure 12 - No propagation.

Next test with mines against side of pipe - 6 surrounding mines Figure 13 no propagation - Figure 14

D op tests - Mine dropped 10 times from 2 feet above rack (Figure 15) - no detonation. Mine then placed on edge and detonated with blasting cap placed between pipes (Figure 16) - Propagation due to line of sight fragments hitting mines. (Figure 17)

To test effects of detonation on an operator if incident occurred while mine was being carried on pole (Figure 18).

& Two mines below propagated - but no sign of damage to mannekin. Only slight damage to pole (Figures 19 & 20)

As results of these tests the storage facility was designed to contain 519 pipes where previously only 64 mines were stored with no guarantee of non propagation.

Conclusions:

The results of these tests show propagation characteristics for the XM41 Aerial Mine:

Armed XM41 Mines may propagate at four or more feet separation when no barrier exists which will deflect fragments. Therefore, the previously established safe separation distance of 2 feet for armed XM41 Aerial Mines is invalid.

Propagation of armed XM41 Mines occur as the result of fragment impact rather than from blast pressure, unless mines are within a few inches of each other.

Armed XM41 Mines will not propagate at a separation distance of less than eight inches when proper shielding between mines is provided.

A donor of two XM41 Mines will not cause propagation of an armed XM41 Mine when separated by eight inches with a proper barrier placed between.

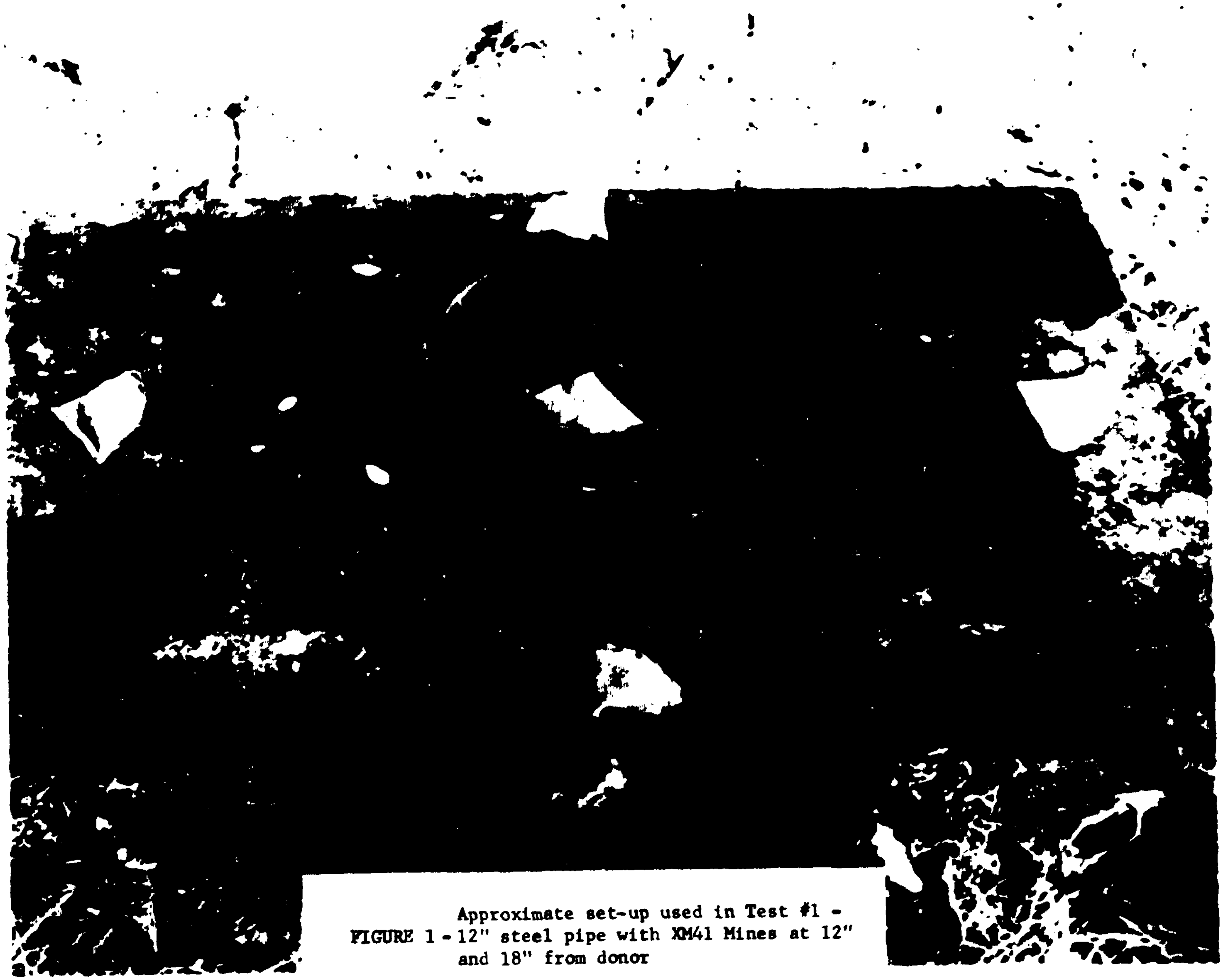
The storage configuration shown in Figure 10 and 11 will provide adequate protection from propagation of armed XM41 Mines stored in a conditioning chamber.

By using the storage configuration shown in Figures 10 and 11 the storage capacity of the conditioning chamber (Bay 1 of Bldg. 3109) can be established at 519 units. Larger chambers can be designed for larger capacity (Shown in Figure 11). This storage capacity is approximately an order of magnitude higher than was permitted under the original storage configuration.

Generally, armed XM41 Mines will not detonate when dropped on the storage rack from two feet above.

In case of an unexpected detonation, the storage rack and safety equipment will protect the operator from all but trivial injury -- if the armed mines are stored and handled in the recommended manner.

Reference 1 - Design of a Facility for the Safe Storage of Armed XM41 Aerial Mines - Stanley Wachtell - Picatinny Arsenal Technical Report No. 3650, December 1967



Approximate set-up used in Test #1 -
FIGURE 1 - 12" steel pipe with XM41 Mines at 12"
and 18" from donor

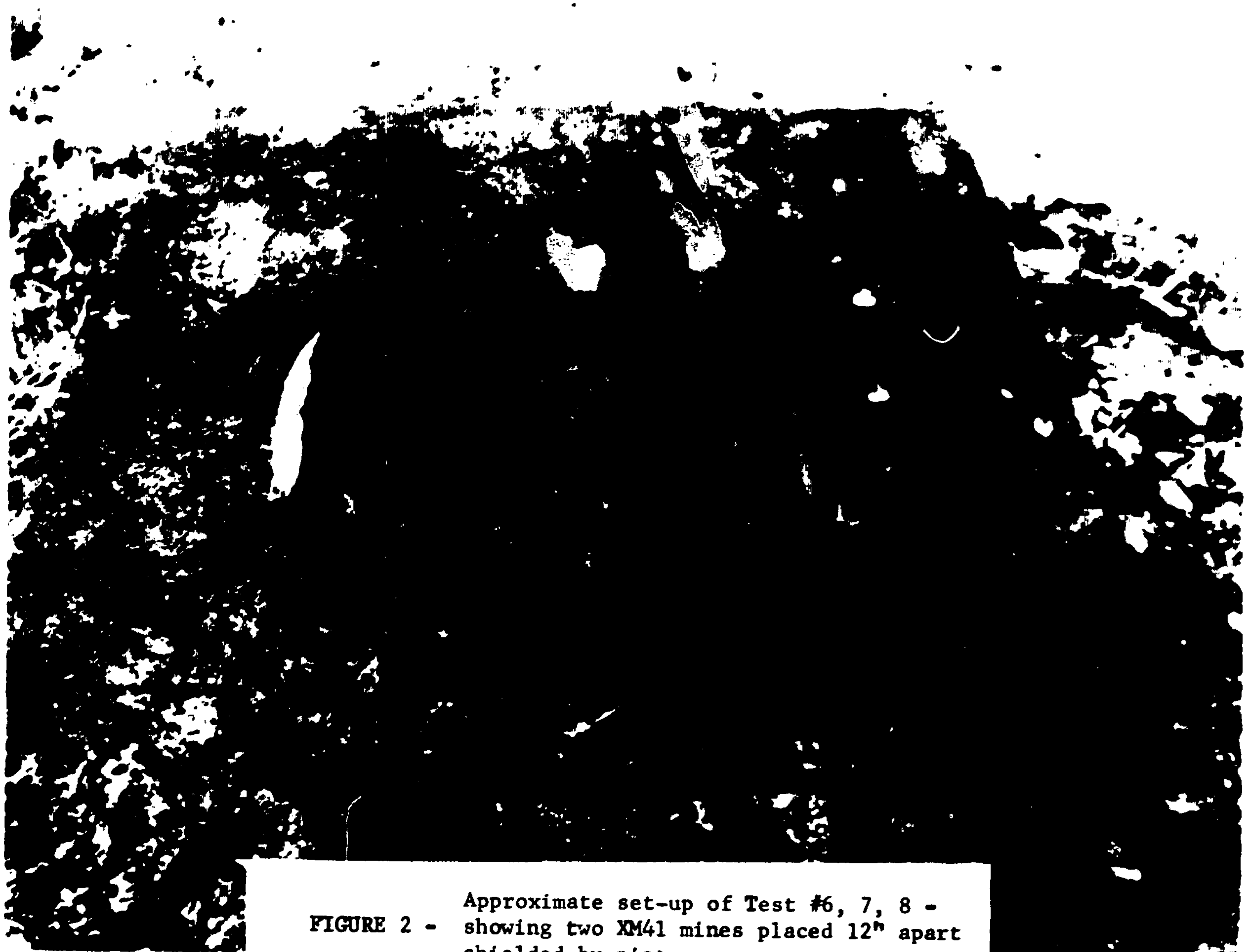


FIGURE 2 - Approximate set-up of Test #6, 7, 8 - showing two XM41 mines placed 12" apart shielded by pipe

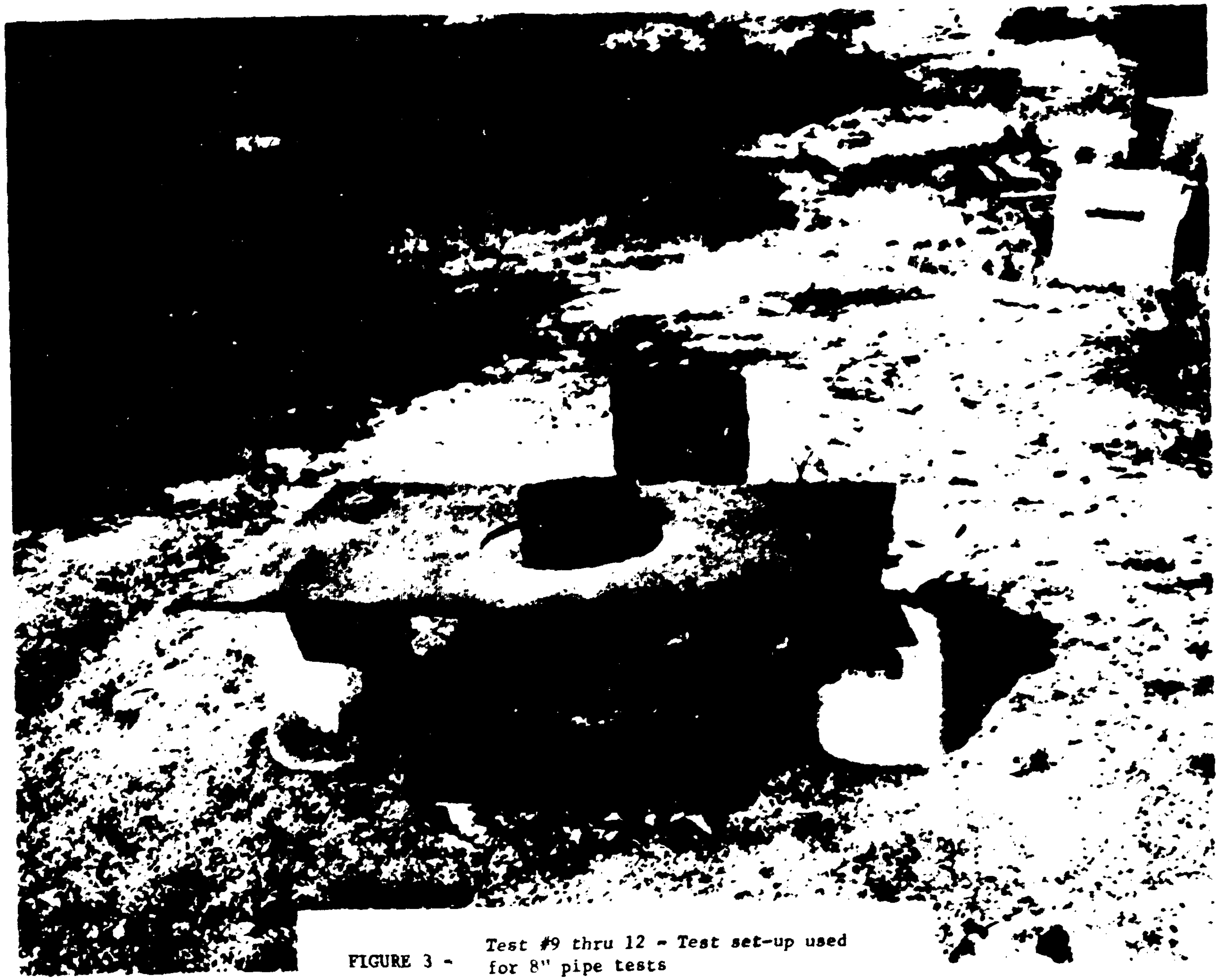


FIGURE 3 - *Test #9 thru 12 - Test set-up used for 8" pipe tests*

FIGURE 4 - Test #13 - Propagation tests of XM41 Mines on steel plate - acceptors 24" and 42" from donor - Both acceptors propagated

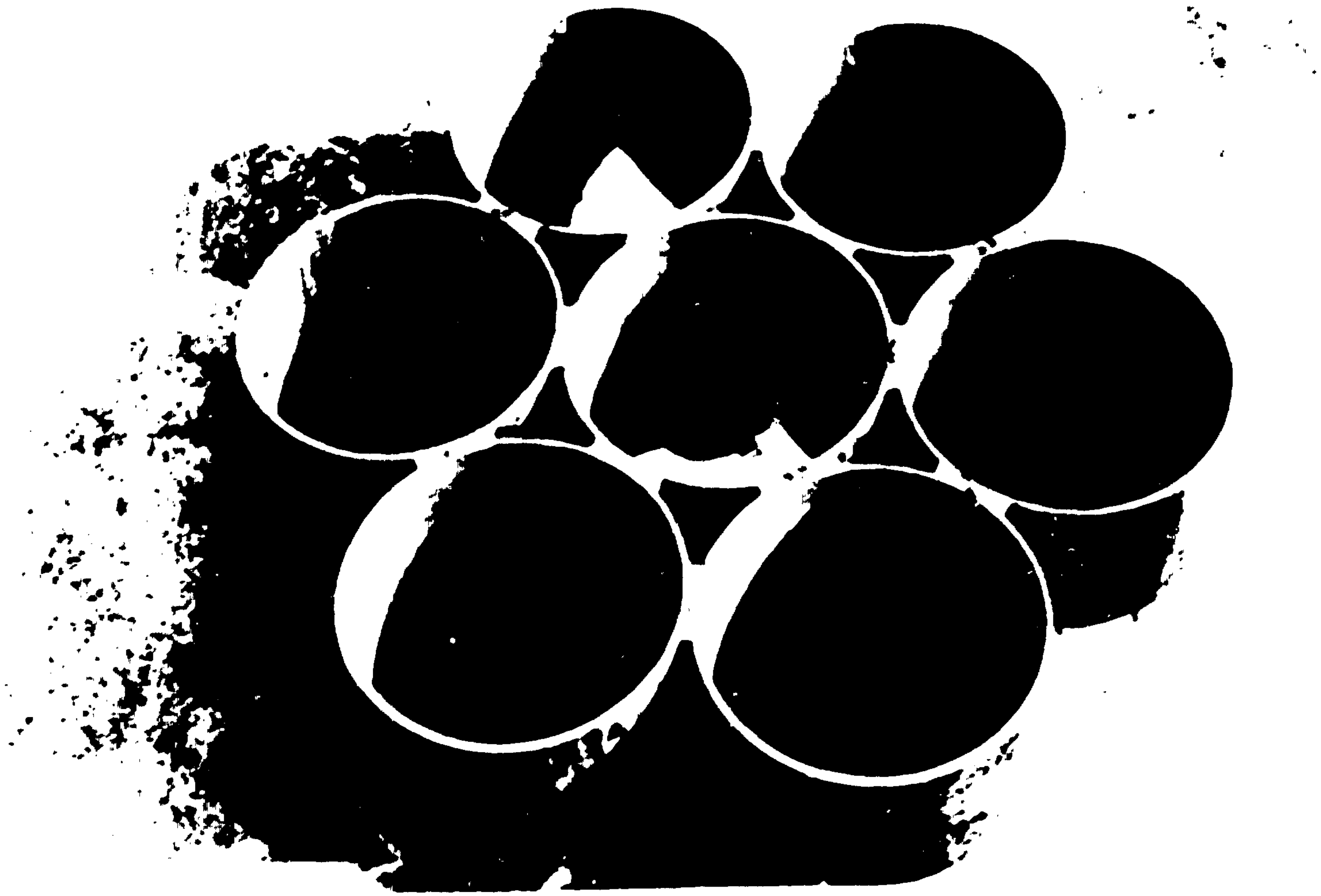


FIGURE 5 - Test #14 - Set up showing 8" pipe cluster on steel plate - 2 donor mines in center unit - 3 acceptors propagated

FIGURE 6 - Test #15 - 8" pipe cluster on plywood sheet. Result shows 5 acceptors propagated - one acceptor thrown out about 12 feet

FIGURE 7 - Test #18 - Step test fixture with two XM41 mines as donor in upper unit

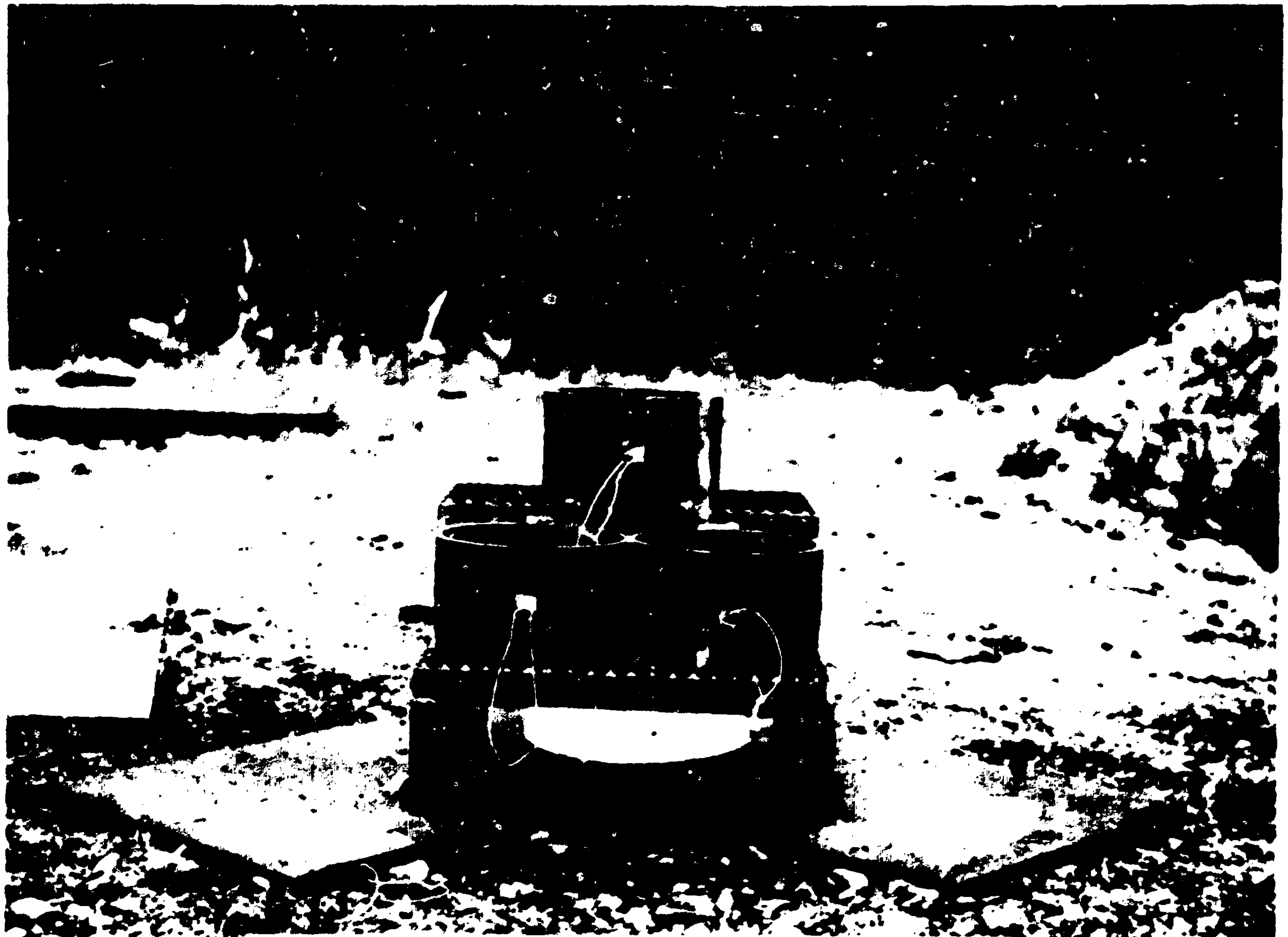


FIGURE 6 - Tests #19-21 - Step Test fixture with two XM41 Mines as donor. Polyfoam sheet under doncr to absorb fragments.

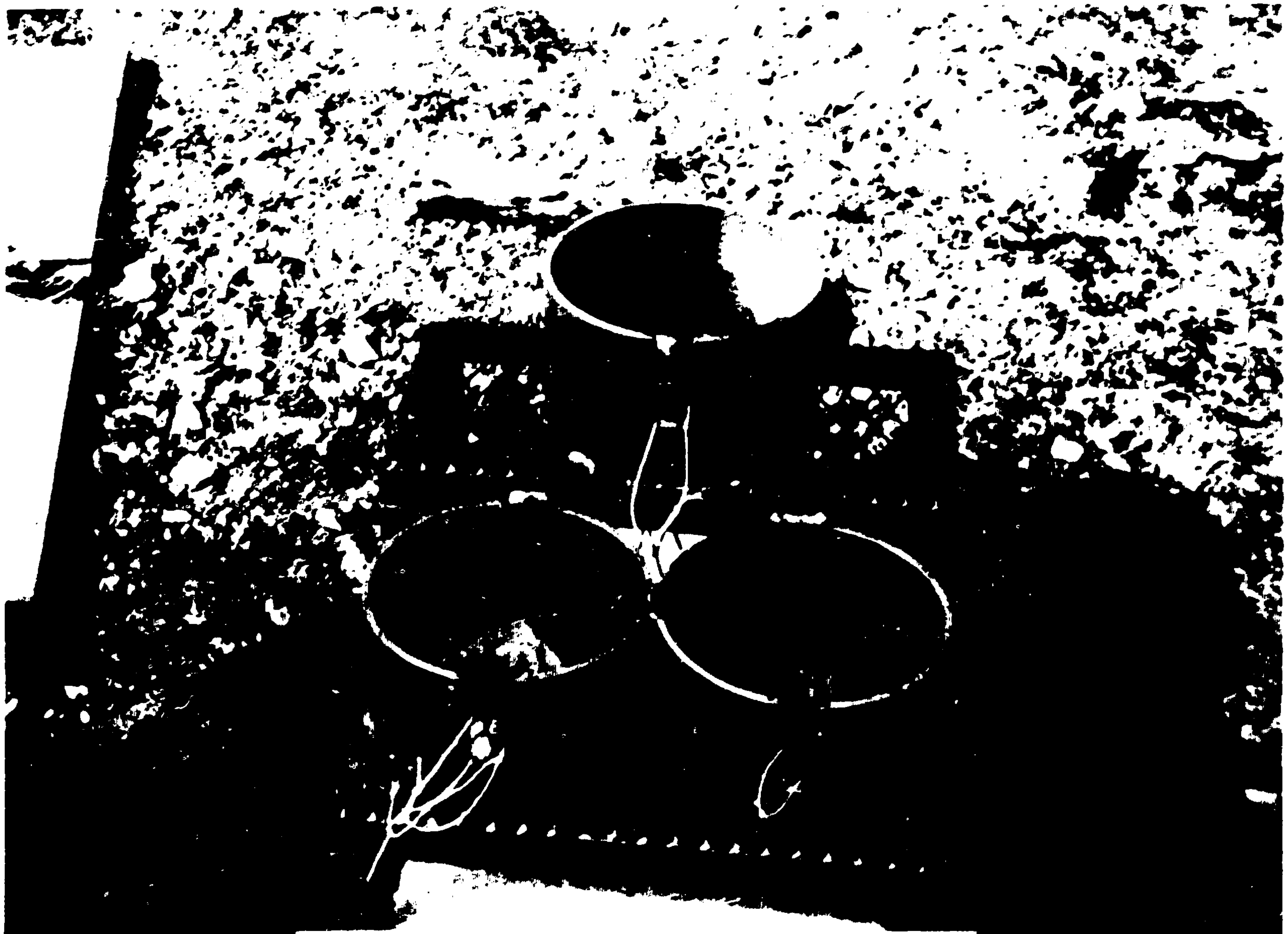


FIGURE 9 - Tests #22-25 - Step est fixture with two XM41 mine donors in lower step. One with thick polyfoam sheet under donor

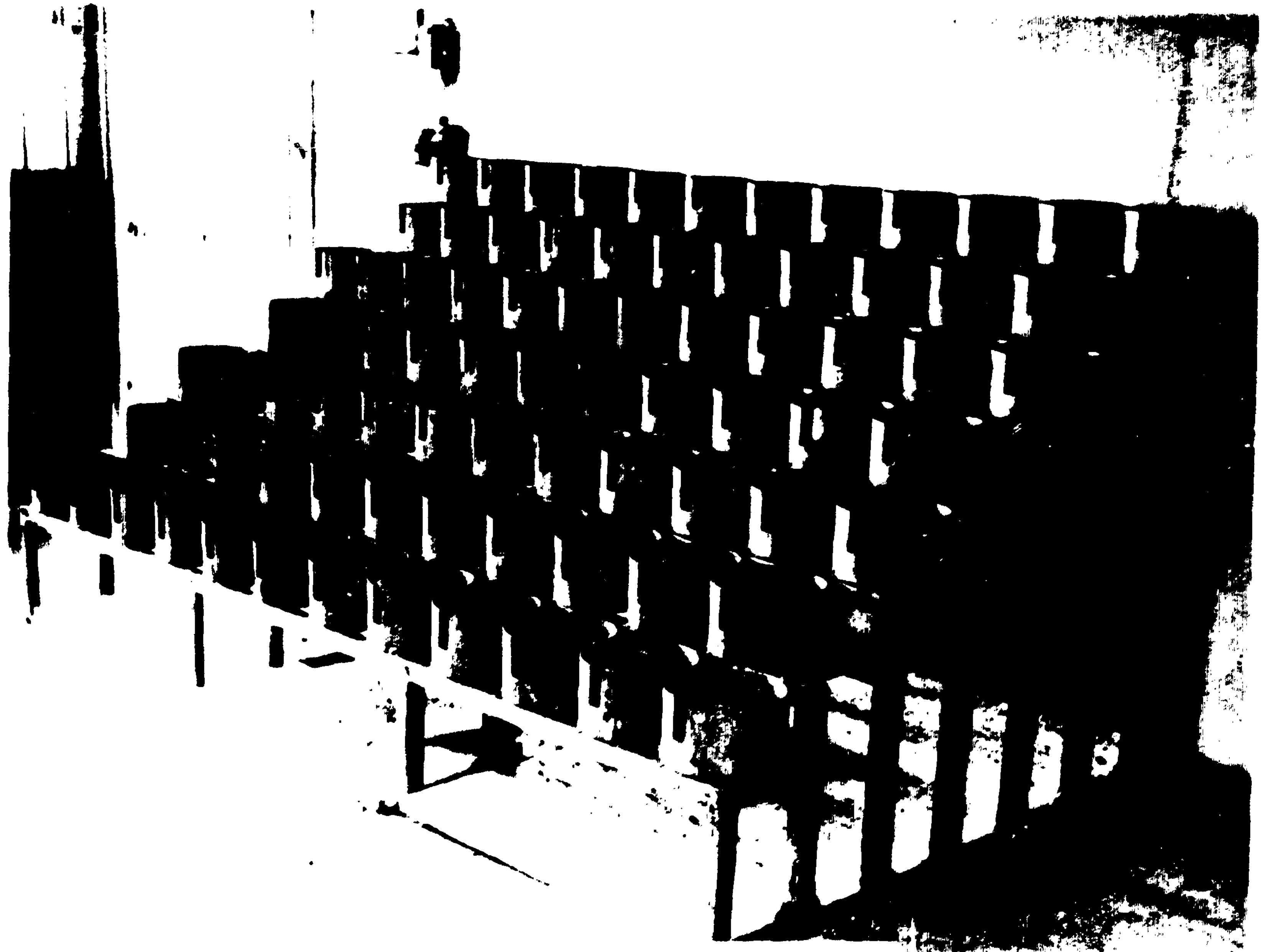


Figure 10 Storage Racks designed to hold XM41 Mines in Conditioning Chamber

Figure 11 Test #28- Test of XM41 mines in storage rack. Two donors in unit marked xx. One acceptor in each of eight surrounding units.

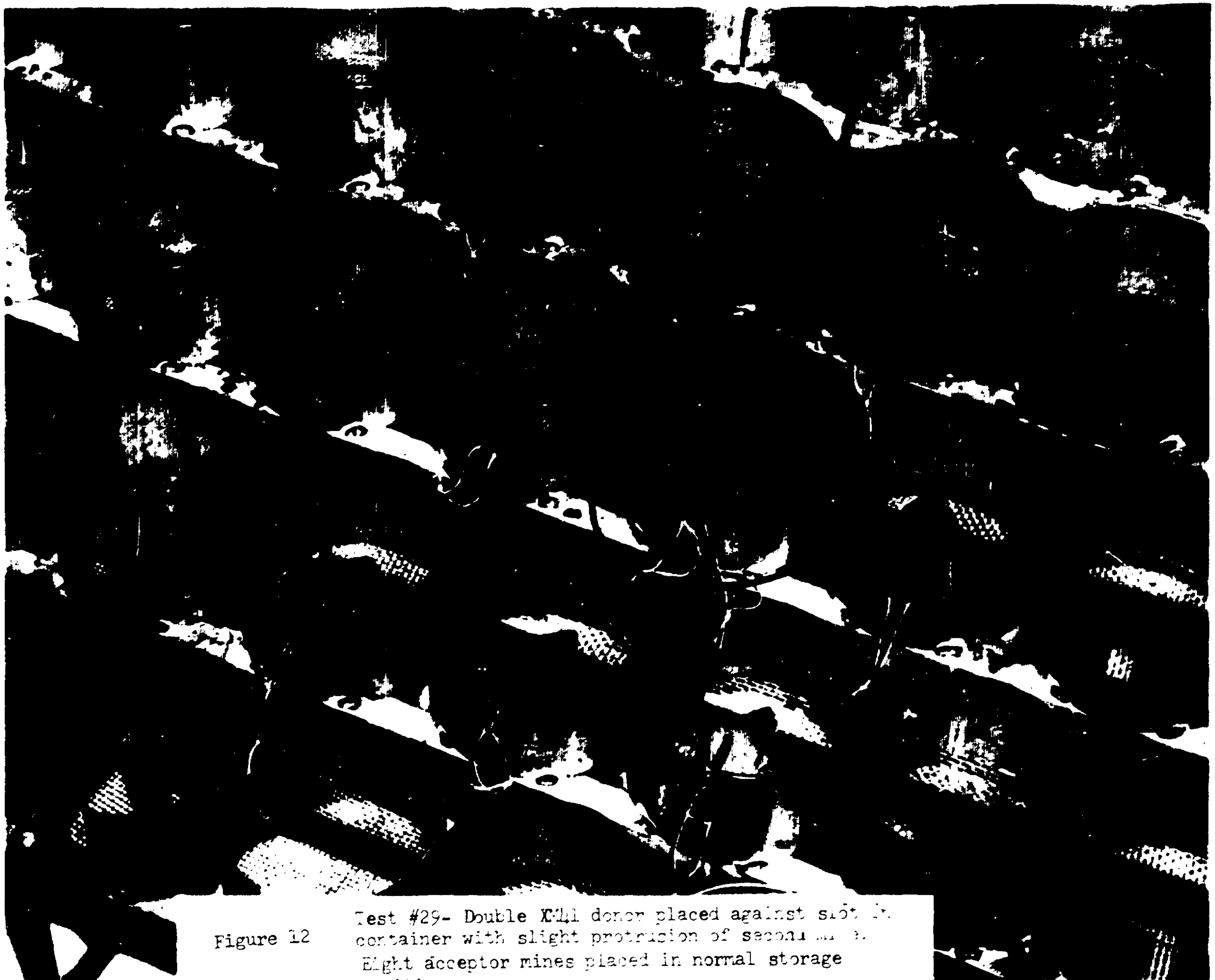


Figure 12 Test #29- Double [illegible] donor placed against slot in container with slight protrusion of second [illegible]. Eight acceptor mines placed in normal storage position.

Figure 13 Test # 30- Test set-up with donor and acceptor mines resting against container walls. Double XM41 donor, six XM41 acceptors used. This represents the worst condition for propagation due to fragments in this storage configuration.

Figure 14 Results of test #30 showing no propagation of acceptors. Very slight additional distortion of donor container unit.

Figure 15 Test #31- Armed XM41 mine suspended two feet above the storage rack.

Figure 16 Test #[illegible]- Armed [illegible] mine placed on edges of storage unit to [illegible] possible detonation at impact of two foot drop.

Figure 17 Result of test #32- showing damage to rack after detonation of a total of six mines.

Figure 18 Test #33- Set-up used to test effects on operator of detonation occurring at end of eight foot wood pole. Donor held two feet above storage rack, on pole in hands of mannekin. Left hand of mannekin 5 feet from donor-body, 6 feet from donor.

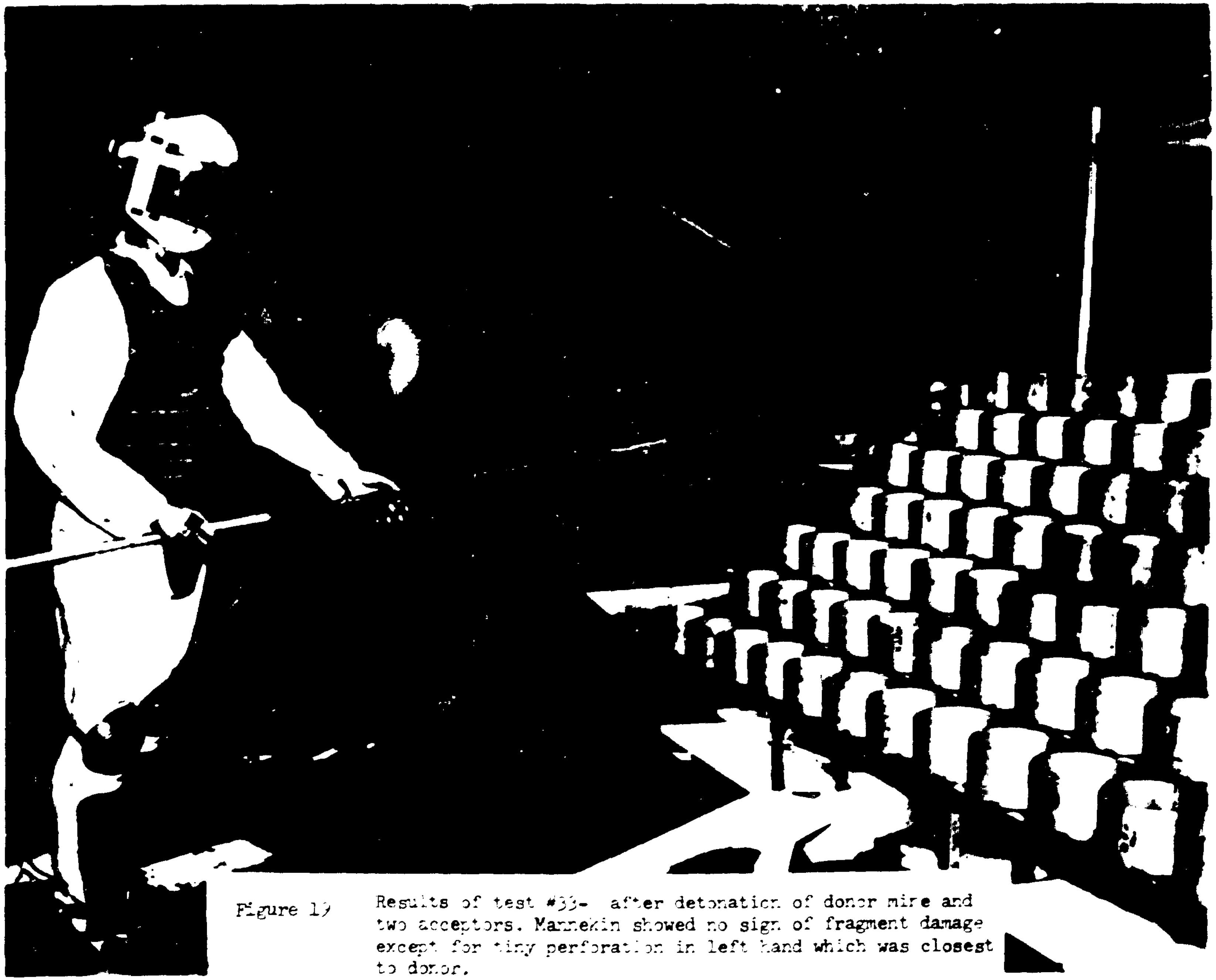


Figure 19 Results of test #33- after detonation of donor mine and two acceptors. Mannekin showed no sign of fragment damage except for tiny perforation in left hand which was closest to donor.

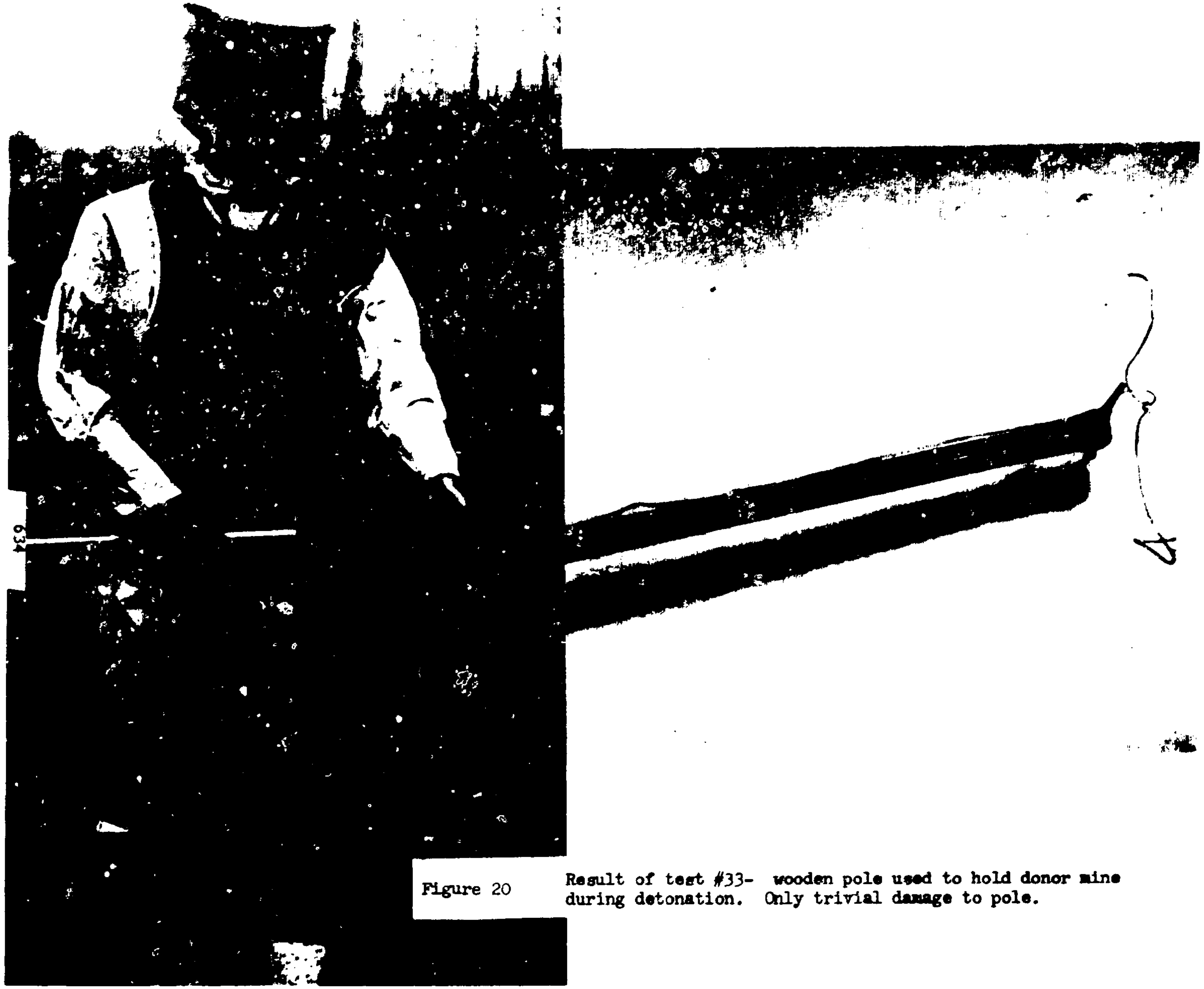


Figure 20 Result of test #33- wooden pole used to hold donor mine during detonation. Only trivial damage to pole.

LIQUID PROPELLANT EXPLOSIVE EQUIVALENCIES

AND EVAPORATION RATES

Moderator: W. Paul Henderson
Edgewood Arsenal
Maryland

LIQUID PROPELLANT EXPLOSIVE EQUIVALENCIES AND EVAPORATION RATES

SUMMARY

Five presentations were made during this session, four follow. After completion of these presentations, a discussion period followed. This was a very spirited and active question and answer session in which most of the audience participated. As a result of this discussion, the consensus of opinion was that the "Quantity Distances" should not be determined by "TNT Equivalencies" alone. Also that in the case of nonflammable, nonexplosive propellants such as the oxidizers, TNT equivalency was not a valid yardstick. They felt that other factors, such as toxicity, flammability and acoustic energy hazards should also be included and would result in more realistic quantity-distance tables.

The moderator recommended that the Work Group be reconvened to discuss the possibility of changing the basis for determining QD tables for liquid propellants as recommended during the Seminar.

PROJECT PYRO

LIQUID PROPELLANT BLAST HAZARDS PROGRAM

by

Robert Thomas
Air Force Rocket Propulsion Laboratory
Edwards, California

ABSTRACT

The objective of Project PYRO was to develop a method for predicting the blast hazard of liquid propellant missiles and space vehicles. The basic test approach was to determine the effects of certain parameters on explosive yield where explosive yield is the equivalent yield in TNT divided by the total propellant weight.

The parameters studies were:

Propellant type, propellant weight, propellant length to diameter ratio, propellant orientation, propellant velocity, propellant confinement within the missile, propellant confinement by the ground surface, and propellant mixing time.

Given a selected failure mode, the PYRO prediction methods will give a terminal yield value and pressure-distance and impulse-distance corrections factors.

BLANK PAGE

HAZARDOUS EXPLOSIVE PROBLEMS AT THE KENNEDY SPACE CENTER

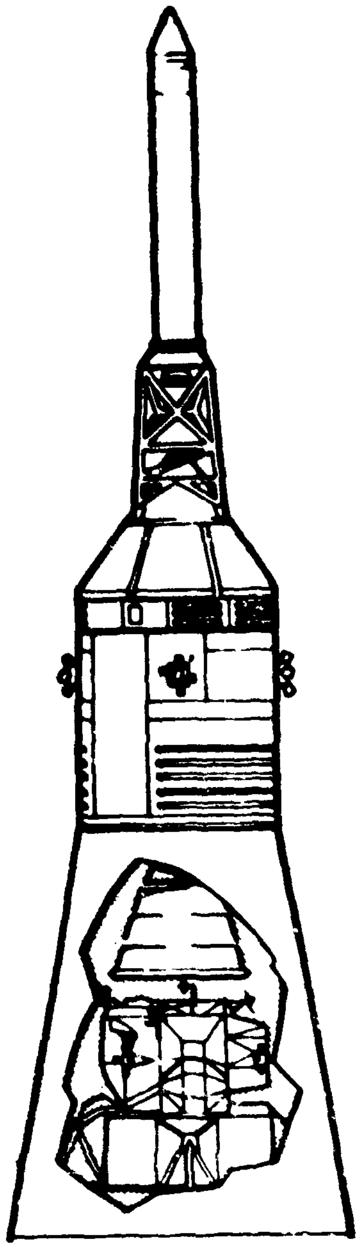
by

Fred X. Hartman
NASA, John F. Kennecy Space Center
Cocoa Beach, Florida

ABSTRACT

The propellant weights, locations, and TNT equivalencies were outlined for the Apollo/Saturn V Space Vehicle as shown in Figures 1 thru 5.

The Apollo/Saturn V Total TNT Equivalency, Blast Danger Area, Expanded Launch Danger Area and Launch Impact Limit Lines were explained in detail using Figure 6.



APOLLO SATURN V
LAUNCH ESCAPE SYSTEM

Class 2 Solid Propellant - Fire Hazard

Pitch Control Motor:

8.87 lbs. GCR 231A
1.8 Ft. length, 8.75 inches diameter
0.62 seconds at 2170 lbs. thrust

Jettison Motor:

204.00 lbs. TP-E-8104
4.6 ft. length 2 ft. 2 ins. diameter
1.2 seconds at 33,000 lb. thrust

Launch Escape Motor:

3170 lbs. GCR 231A
15 ft. length 2 ft. 2 inches diameter
3.23 seconds at 139,400 lbs thrust

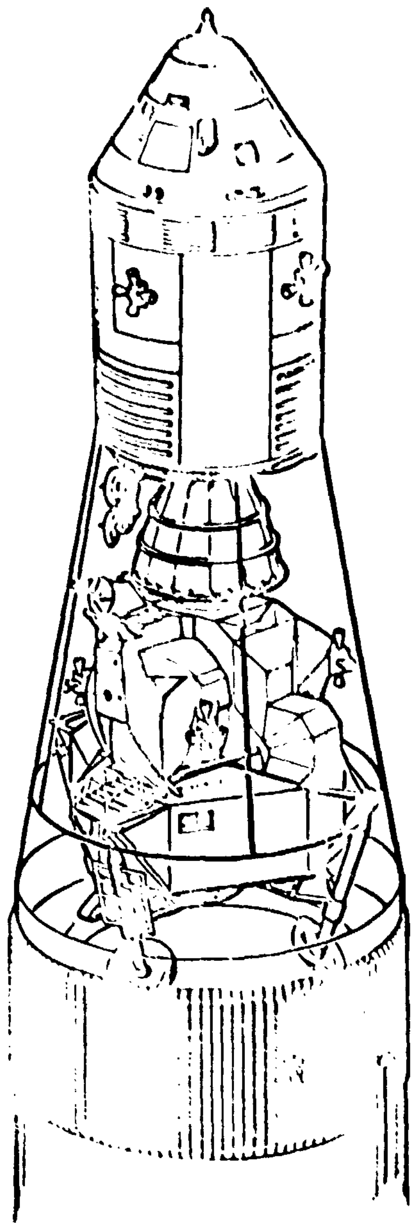
3382 lbs. Total

Launch Escape System TNT Equivalency at 5% = 169#

Quantity-Distances

Inhabited Buildings Feet		Public Highways Feet		Intraline Feet	
Bar	Unbar	Bar	Unbar	Bar	Unbar
235	470	140	280	50	100

Figure 1



COMMAND MODULE

RCS (N_2O_4 and MMH)

N_2O_4	2 @ 89.2 ea.	=	178.4
MMH	2 @ 45.2 ea.	=	90.4

26.8 lbs. TNT for C/M 268.8# @ 10% = 26.8# TNT Equivalency

Command Module TNT Equivalency = 26.8#

Figure 2

SERVICE MODULE

SPS (N_2O_4 and Aero-50)

N_2O_4 - 1 Storage -	11,284.69#	
Aero - 50-1 Storage	7,058.36#	
N_2O_4 - 1 sump	13,923.72#	
Aero - 50 - 1 sump	8,708.10#	
	40,974.87#	@ 10% = 4,097# TNT Equivalency

RCS (N_2O_4 and MMH)

N_2O_4 - 4 Primary @ 137# ea =	548.0	
MMH - 4 Primary @ 69# ea =	276.0	
N_2O_4 - Reserve @ 89.2# ea =	356.8	
MMH - 4 Reserve @ 45.2 ea =	180.8	
	1,361.6#	@ 10% = 136 # TNT Equivalency

Tanks for Fuel Cells (LH_2 and LO_2)

LO_2 - 2 Tanks @ 320# ea =	640	
LH_2 - 2 Tanks @ 28# ea =	56	
	696#	@ 60% = 418# TNT Equivalency.

Service Module TNT Equivalency = 4,651#

<u>Quantity Distances</u>

Inhabited Buildings Feet		Public Highways Feet		Intraline Feet	
Bar	Unbar	Bar	Unbar	Bar	Unbar
685	1370	410	820	150	300

Figure 2A

LUNAR MODULE

Ascent Stage (N_2O_4 and Aero - 50)

N_2O_4	3,200 lbs.
Aero - 50	1,995 lbs.
	5,195 # @ 10% = 520# TNT Equivalency

Descent Stage (N_2O_4 and Aero - 50)

N_2O_4	5,500 lbs.
Aero 50	1,100 lbs.
	6,600 # @ 10% = 660# TNT Equivalency

RCS (N_2O_4 and Aero - 50)

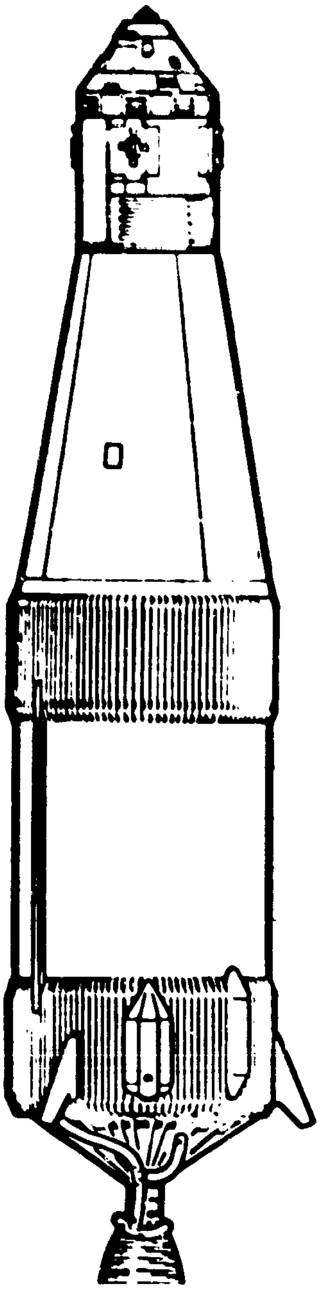
N_2O_4 -	408 lbs.
Aero 50	208 lbs
	616 # @ 10% = 61.6 TNT Equivalency

Lunar Module TNT Equivalency = 1,241 #

Quantity Distances

Inhabited Buildings Feet		Public Highways Feet		Intraline Feet	
Bar	Unbar	Bar	Unbar	Bar	Unbar
460	920	275	550	105	210

Figure 2B



S IV B Third Stage Saturn V

LO_2 197,000#

LH_2 43,000#

240,000# @ 60% = 144,000# TNT Equivalency

APS 6 gal. MMH = 44#

6 gal. N_2O_4 = 72#

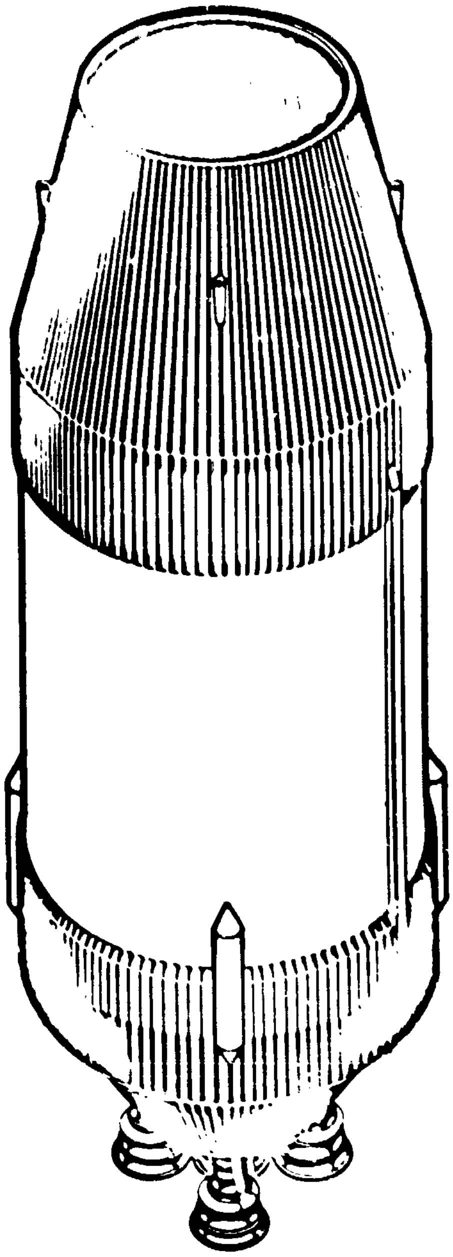
116# @ 10% = 11.6 TNT Equivalency

S IV B TNT Equivalency = 144,012#

Quantity Distances *

Inhabited Bldgs Feet		Public Highways Feet		Intraline Feet	
Bar	Unbar	Bar	Unbar	Bar	Unbar
2294	3769	1516	2261	469	938

Figure 3



S-II Second Stage Saturn V

LO_2	788,958#	
LH_2	157,800#	
	946,758#	@ 60% = 568.054# TNT Equiv.

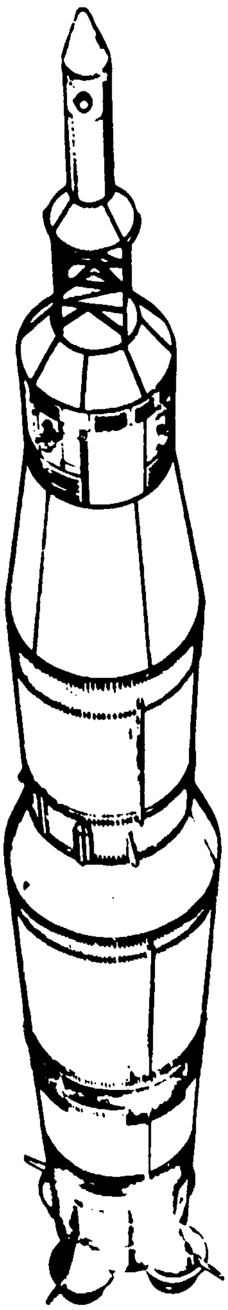
S II TNT Equivalency = 568,054#

Quantity-Distances *

Inhabited Bldgs. Feet		Public Highways Feet		Intraline Feet	
Bar	Unbar	Bar	Unbar	Bar	Unbar
5744	5744	3446	3446	759	1518

* Interpolated

Figure 4



S IC First Stage Saturn V

LO_2	3,253,140#
RP-1	1,400,800#
	4,653,940#

500,000# @ 20% =	100,000#	TNT Equivalency
4,153,940# @ 10% =	415,394#	TNT Equivalency
	515,394#	TNT Total Equivalency

Quantity-Distances *

Inhabited Bldgs. Feet		Public Highways Feet		Intraline Feet	
Bar	Unbar	Bar	Unbar	Bar	Unbar
5485	5485	3290	3290	725	1450

* Interpolated

Solid Rocket Motors

S IVB

Ullage - Class 2

2 @ 58.8# each = 117.6#

S II

Ullage - Class 2

2 @ 336# each = 2688.0#

Retro Class 2

4 @ 268.2# each = 1172.8#

S IC

Retro - Class 2

8 @ 278# each = 2224.0#

Launch Escape System 3382.0#

Class 2 9584.4# Total

Figure 5

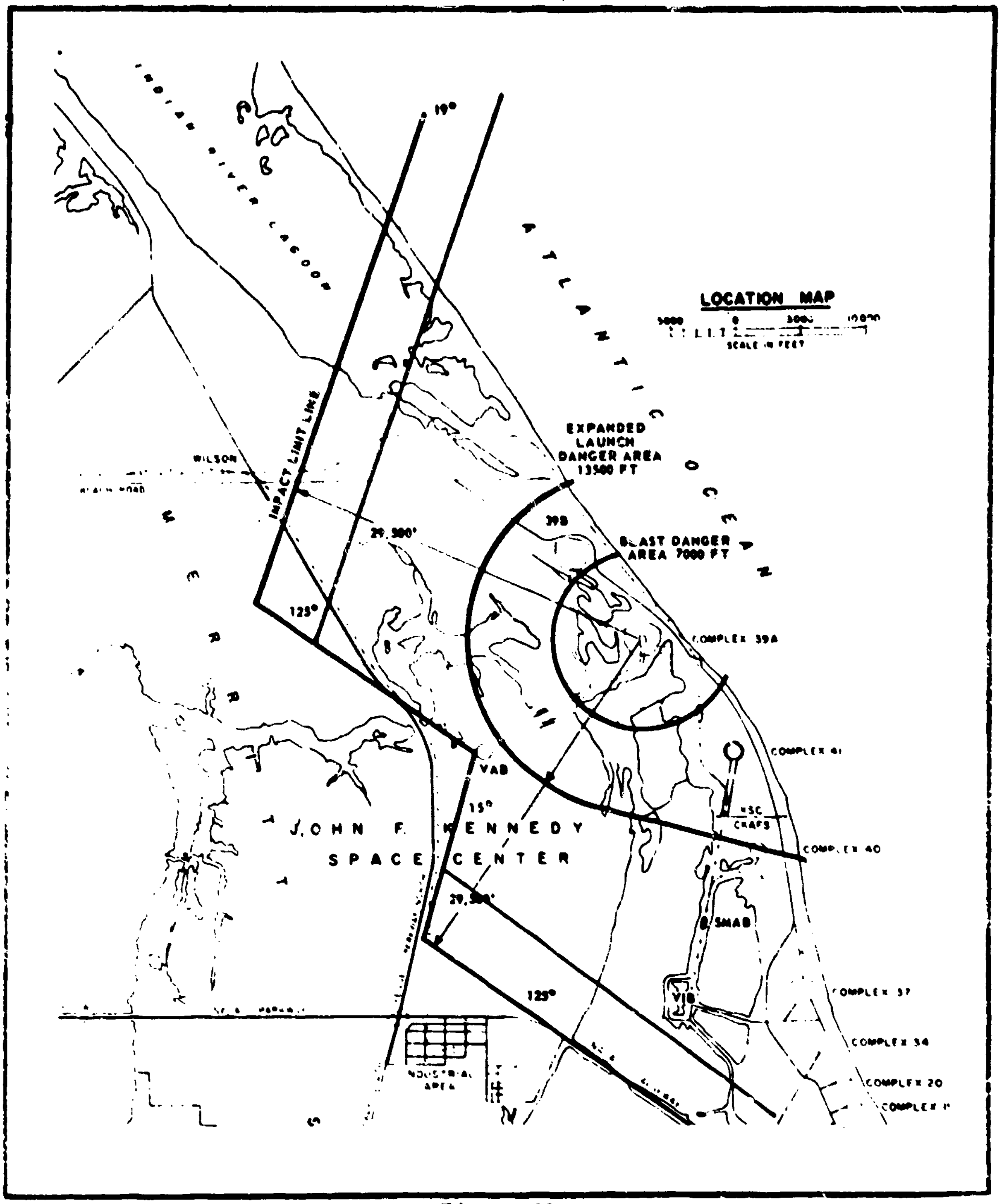

LOCATION MAP
SCALE IN FEET
EXPANDED
LAUNCH
DANGER AREA
13500 FT
BLAST DANGER
AREA 7000 FT
IMPACT LIMIT LINE
WILSON
COMPLEX 39A
COMPLEX 41
COMPLEX 40
COMPLEX 37
COMPLEX 34
COMPLEX 20
39B
VAB
JOHN F. KENNEDY
SPACE CENTER
SMAB
VIB
125°
15°
19°
29,300'
ATLANTIC OCEAN
INDIAN RIVER LAGOON

Figure 6A

APOLLO/SATURN V TOTAL TNT EQUIVALENCIES

LES	SOLID	3382.0#)	
		)	479# = TNT Equivalency
Retros & Ullage	SOLID	6202.0#)	
C/M		26.8#	
S/M		4372.0#	
LM		1241.0#	
SIVB		144,000.0#	
SII		568,055.0#	
SIC		515,394.0#	
		1,233,088.8#	
		1,233,088.8#	Total Liquid TNT Equiv.
		479.0#	Total Solid TNT Equiv.
		1,233,567.8#	Overall Total TNT Equiv.

<u>Quantity-Distances</u>

Inhabited Buildings Feet		Public Highways Feet		Intraline Feet	
Bar	Unbar	Bar	Unbar	Bar	Unbar
8010	8010	4805	4805	1060	2120

Figure 6B

TNT EQUIVALENCY
A VALID OR OUTMODED CRITERIA

by

Paul V. King
Manager of Safety
General Electric Company
Bay St. Louis, Mississippi

ABSTRACT

This paper presents a very brief discussion of some of the anomalies resulting from the use of TNT equivalents to evaluate liquid and solid propellant hazards, a summation of the continuing development and refinement of hazards criteria as pursued by the ASESB and other agencies, and an outline of needs for the immediate future.

SUMMARY

There exists a need for meaningful evaluation criteria to assess and quantify the risks involved in siting, operation and storage of explosives and propellants for military and aerospace activities.

Although adequate safety has been provided by the criteria presently applied by DOD, the tremendous increase in bulk of materials used for aerospace activities and the advances in technology in recent years have highlighted this problem.

An attempt to fulfill this need by reference to "TNT Equivalency" is not completely satisfactory since it sometimes oversimplifies or conversely overlooks the most important hazard in a given situation. In a number of cases, application of the TNT equivalency concept results in prohibitively costly controls and facilities without really assuring safety.

Although TNT equivalency has a degree of validity in evaluating the potential yield in terms of overpressure, at a given distance, it does not indicate the probability of a given yield nor the manner in which the yield varies as a function of mass or with the type of accident (failure mode). As a result safety controls, in terms of operational interference facility siting and construction, etc. may represent an increasingly large increment of total project funds as quantities of the propellants, explosives, materials involved increase. In addition, the TNT equivalency concept leads to a criteria based on an assumed overpressure in terms of pounds per square inch rather than on fragmentation, fire and/or toxicity, which are more likely to be the controlling factors.

METEOROLOGY AND ATMOSPHERIC DIFFUSION FROM LIQUID PROPELLANT EVAPORATION

by

Paul A. Humphrey
National Air Pollution Control Administration
Durham, N.C.

ABSTRACT

For the purpose of illustrating the role of the meteorologist and inviting questions, a practical problem is discussed that assumes a spill of dimethyl hydrazine while a rocket is being fueled. A step-by-step explanation is given of how an atmospheric diffusion equation is used to determine the area that should be evacuated. The size of the evaporation area makes it necessary to determine the location of a virtual point source, and consideration is taken of predicted wind direction changes.

The problem and its solution can be found on pages 55-56, Workbook of Atmospheric Dispersion Estimates, Public Health Service Publication No. 999-AP-26, National Center for Air Pollution Control, Bureau of Disease Prevention and Environmental Control, U. S. Department of Health, Education, and Welfare, Cincinnati, Ohio, 1967.

SAFE DISPOSAL OF EXPLOSIVE MATERIAL IN ACCORDANCE

WITH CLEAN AIR LEGISLATION

Moderator: Pope A. Lawrence
Scientist Director
PHS, Federal Facilities Section
Abatement Program
National Air Pollution Control Administration
Washington, D. C.

SAFE DISPOSAL OF EXPLOSIVE MATERIAL IN ACCORDANCE WITH CLEAN AIR LEGISLATION

SUMMARY

The moderator opened the session by discussing Public Law 90-148, November 21, 1967 known as the Air Quality Act of 1967. This act revised and restates Federal Clean Air legislation. It will inevitably affect future disposal of explosive materials at Federal installations and industrial plants required to cooperate with local, State, and regional Air pollution Control agencies.

Under the new Act, the Secretary of Health Education and Welfare has announced plans to designate, by June 1969, 32 or more Air Quality Control Regions throughout the United States collectively containing about 64% of the urban population. He will then publish air quality criteria and reports on control techniques for harmful pollutants such as sulfur oxides and particulates. Ultimately, criteria will include oxides of nitrogen which are among the chief combustion products of explosives. After air quality criteria and recommended control techniques have been issued the States have a limited time within which to adopt ambient air quality standards applicable to any designated air quality control regions or portions thereof within such States. If the States do not act, then the secretary of HEW is authorized to promulgate the standards.

The moderator emphasized that present regulations of the Department of Health Education and Welfare issued pursuant to Executive Order 11282, May 26, 1966, permit the open burning of deteriorated and unused explosives. This traditional practice is still allowed because alternative technology has not been available. He observed, however, the growing need for developing such technology because of increasing population pressure near many Federal installations accompanied by stepped up local air pollution control legislation and enforcement activity.

Dimensions of the nation's overall explosive waste disposal problem are not presently clear, said the moderator, and he called upon the seminar participants to discuss their current practices and any new technology being developed to reduce the necessity for open burning.

Mr. George L. Wyatt, Chief Industrial Hygienist at Marshall Space Flight Center, reported on information he had gleaned from four major installations of NASA. Disposal of explosives seems to be inconsequential at those sites. Disposal of contaminated fuels, solvents, and other liquid wastes (some containing cyanide) is handled in a variety of ways. He mentioned a propane fueled incinerator for reduction of nitrogen tetroxide in use at White Sands Missile Range.

Mr. C. D. Attaway, Thiokol Chemical Corporation, discussed techniques for pyrotechnic disposal at Longhorn Amunition Depot. He mentioned that emission of highly toxic flourine compounds had been eliminated when diesel oil was substututed for freon as a wetting agent prior to burning certain types of sensitive materials.

The meeting was then opened for remarks and questions by all participants. The lively discussion indicated that present methods for disposal of explosive or toxic materials include some open burning, incineration with absolute filtration of combustion products, some chemical deactivation (of lead azide, for example), burial at sea, injection of liquid waste underground or by regulated discharge to surface streams. One noteworthy item was the discovery of a commercial market for concentrated wastes from TNT manufacture. This material which formerly caused "red water" complaints is now sold in tank car quantities to a nearby paper mill. Several speakers noted increased pressure for State and local pollution control inspectors. There seems to be a growing practice at larger installations to establish special committees with prime concern for minimizing air and water pollution.

The moderator's overall reaction to this seminar is that prevention of environmental pollution is the serious concern of responsible persons in the explosives industry. He feels it appropriate to suggest that the Armed Services Explosive Safety Board might consider initiating a study to reveal dimensions of present and especially future explosive waste disposal requirements. Precise information might help stimulate development of improved methods for disposal or even conversion to marketable chemical products. Hopefully methods other than open burning will be available when the time comes to phase out some explosives production because of reduced military requirements.

AMMUNITION PACKAGING PROBLEMS AND MATERIALS HANDLING

Moderator: K. E. Valant
AMC Ammunition School
Savanna Army Depot
Illinois

AMMUNITION PACKAGING PROBLEMS AND MATERIALS HANDLING

SUMMARY

Problems in packaging constituted approximately 75% of the discussion in specialist sessions on the subject areas of "Explosives Transportation Problems-Land and Water", "Transportation Regulations for Ammunition and Explosives", and "Air Transportability of Ammunition and Explosives and Safety Problems". All of these sessions preceded this subject session in the agenda of the Seminar.

The above condition was anticipated; therefore, the moderator had requested a representative of each of the Services to present problem areas of unique nature for discussion by the attendees. The representatives and the discussion areas were:

1. Mr. Gordon Mustin, Hq Naval Ordnance Systems Command.

Problem: The increasing use of a variety of plastic materials in packaging of ammunition and explosives increases the flammability hazard aboard ship and in storage. Discussion revealed that this is becoming a more complex problem. In addition to increased flammability, the plastics provide inadequate electromagnetic protection, particularly needed during vertical replenishment of ships or similar logistic actions on land. Most plastics are non-conductive, thereby increasing the static electricity hazard. As demonstrated by test, wood or fiberboard materials provide greater protection than most plastics. Basic to the problem is the lack of adequate design criteria and test procedures and equipment for material application and evaluation. The existing "blow-torch" testing technique is not sufficiently discriminating, although, it provides some indication of protection.

2. Mr. Robert Ervin, U. S. Army Materiel Command Ammunition Center, Savanna Army Depot.

Problem: Material handling equipment needs and new items being tested for suitability to meet those needs within the USAMC ammunition depot system. New standardized electric fork lift trucks, a high volume straddle-type trailer for intra-installation movement, and problem areas forecasted for handling and loading of SEA/LAND containers or special designed "gondolas" for ammunition and explosives. Discussion included problems of handling unitized loads aboard ships or at ship's side when the commodity extends beyond the unit base. Contact of the handling gear onto the item in these cases places excessive stress on the items resulting in physical damage to the unitization of the items. Limitations of overhang and unitizing techniques per MIL STD 147B should be re-evaluated, along with rough handling testing methods employed for packing designs. These conditions also result in excessive effort and cost for adequate stowage and securement in the vessels' holds.

3. Mr. Orlin Brown, Hq U.S. Air Force Systems Command.

Problem: Qualification of new or revised packaging for ammunition and explosives for movement under the Code of Federal Regulations is usually accomplished through obtaining and use of Special Permits issued by the federal Department of Transportation. The DOT requires 60 days lead time, and shippers submitting requests which are inadequately justified or described cause the time cycle to break down. Air Force has issued a supplement to the Military Traffic Management Regulation (AR55-355) for guidance in this area. Discussion revealed a universal need for information and guidance by all services designed to augment the basic data in the regulation.

4. Mr. Kenneth Macy, Hq U. S. Army Munitions Command, Picatinny Arsenal.

Problem: Mr. Macy showed views of an assortment of packaging conditions of ammunition and explosives in Viet Nam and discussed changes and corrective actions taken. Most notable were the results of rough physical handling of palletized separate loading projectiles. To update and improve the designs of these pallet loads, a new family of designs has been made and is going into production. These new units are larger and heavier and contain approximately twice the quantity of projectiles over each previous design. Problems of moisture penetration through spirally-wound fiber containers are being solved thru use of "jungle-packing" these containers in preservative. General discussion pursued problems of mortar propellant increment protection from moisture, the physical inadequacy of wire-bound shipping containers, and problems associated with extruded plastic containers for ammunition. No specific packaging design consideration or technique is employed in R & D efforts toward reducing the explosive hazard classification (or storage classification) or in attempting to reduce an enmasse explosive characteristic to one of propagation. These actions, when attempted, usually occur after-the-fact.

The time allotted for this specialist session could not accommodate the great interest and enthusiastic discussion of the subject by the attendees. Many of the problems related to packaging and packing of hazardous materials, as expressed by attendees in this subject session and in others as enumerated, reveals a wide-spread need among the Services for increased emphasis on training. Training is required, not only in gaining knowledge and understanding of established regulatory requirements, but also in the ability to apply established and tested techniques and criteria.

COORDINATION OF TEST, EVALUATION AND SAFETY EFFORTS ON HE FIELD TESTS

Moderator: Jack Kelso
Defense Atomic Support Agency
Washington, D. C.

WHEN MATERIAL IS FURNISHED AN ADDENDUM TO THE MINUTES WILL BE TRANSMITTED.

BLANK PAGE

ATTENDEES

MR. D. F. ABERNETHY
Defense Supply Agency
Cameron Station
Alexandria, Virginia 22314

COL B. B. ABRAMS
Chairman, ASESB
Washington, D.C. 20315

MR. A. E. ADAMS
Naval Air Systems Command
(AIR-4114A)
Washington, D.C. 20360

MR. C. L. ADAMS
Corps of Engineers, USA
Huntsville, Alabama

MR. J. R. ADAMS
Naval Weapons Station
Fallbrook, California 90740

MR. P. E. ADAMS
E. I. du Pont de Nemours & Co.
Martinsburg, West Virginia 25401

MR. D. E. AINSWORTH
Naval Ordnance Systems Support Office
4297 Pacific Highway,
San Diego, California 92110

MR. I. B. AKST
Mason & Hanger-Silas Mason Co.
Amarillo, Texas 79105

MR. E. A. ALLEN
Olin Mathieson Chemical Corp.
Indiana Army Ammunition Plant
Charlestown, Indiana 47111

MR. D. C. ANDERSON
The Richmond Corporation
Redlands, California 92373

MR. G. L. ANDERSON
NASA, JFK Space Center
Kennedy Space Center, Florida 32899

MR. V. W. ANDERSON
NASA, (Code BX)
Washington, D.C. 20546

2LT D. M. ARMSTEAD
Indiana Army Ammunition Plant
Charlestown, Indiana 47111

MR. F. M. ASHCRAFT
Military Airlift Command
Scott AFB, Illinois 62225

MR. A. E. ASHLEY
Indiana Army Ammunition Plant
Charlestown, Indiana 47111

MR. M. M. ASHLEY
USAF, AFSC, APGC (PGS)
Eglin AFB, Florida 32542

MR. J. B. ATKISSON
Jet Propulsion Laboratory
Pasadena, California 91103

MR. C. D. ATTAWAY
Thiokol Chemical Corporation
Longhorn Army Ammunition Plant
Marshall, Texas 75670

MR. L. AVRAMI
Explosives Laboratory FRL,
Picatinny Arsenal
Dover, New Jersey 07801

LT L. E. AYER, JR.
U. S. Naval Ammunition Depot
FPO San Francisco 96612

MR. N. D. BACHTELL
ASESB
Washington, D.C. 20315

MR. MAURICE BAER
Picatinny Arsenal
Dover, New Jersey 07801

MR. M. R. BAILEY
AMC Safety Field Office
Lexington-Blue Grass Army Depot
Lexington, Kentucky 40507

MR. R. W. BAILEY
Munitions Division, ADCSLOG MR
HQ USAREUR & 7th Army,
APO New York 09403

MR. H. O. BAKER
Corps of Engineers, USA,
Huntsville, Alabama

CPT R. W. BAKER
ASESB
Washington, D.C. 20315

MR. W. E. BAKER
Southwest Research Institute
San Antonio, Texas 78228

MR. W. J. BALDWIN
Defense Supply Agency
Cameron Station
Alexandria, Virginia 22314

MR. O. C. BALLANCE
H&HS, MCAS
Yuma, Arizona 85364

MR. CHESTER BARAN
HQ 21 AF (21 NSO)
McGuire AFB, New Jersey 08641

MR. ALFRED BARDEN
Military Traffic Management &
Terminal Service
Brooklyn, New York 11250

MR. E. E. BARILOTTI
NWC Corona Laboratories
Corona, California

MR. KENNETH BARKER
Olin Mathieson Chemical Corp.
Indiana Army Ammunition Plant
Charlestown, Indiana 47111

MR. D. E. BARNETT
Westinghouse Electric Corp.
Astronuclear Laboratory
P.O. Box 10864
Pittsburgh, Pennsylvania 15236

LTC WILLIAM R. BARRETT
Air Force Western Test Range (WTOSM)
Vandenberg AFB, California 93437

MR. A. J. BAUMGARDNER
Fort Wingate Army Depot
Gallup, New Mexico 87301

MR. J. T. BEARDEN
Holston Defense Corporation
P.O. Box 749
Kingsport, Tennessee 37662

MR. A. J. BECHER
Edgewood Arsenal
Edgewood Arsenal, Maryland 21010

MR. BONNEAU A. BEDENBAUGH
North American Rockwell Corp.
Rocketdyne Division
P.O. Box 548
McGregor, Texas

MR. F. E. BELLES
NASA-Lewis Research Center
Cleveland, Ohio 44135

MR. W. J. BENJAMIN
Seneca Army Depot
Romulus, New York 14541

MR. DE L. BENSON
Flight Dynamics Laboratory
Wright Patterson AFB, Ohio

MR. C. L. BERKEY
Naval Weapons Laboratory
Dahlgren, Virginia 22448

MR. G. R. BERRY
AFETR Safety Office (ETD)
Patrick AFB, Florida 32925

MR. R. J. BILLINGSLEY
APGC (PGOWT)
Eglin AFB, Florida 32542

LCDR J. E. BIRON
Naval Weapons Laboratory
Dahlgren, Virginia 22448

MR. G. W. BOLKOW
HQ AFCMD (CMSS)
Air Force Unit Post Office
Los Angeles, California 90045

MR. A.A. BOMBICH
USAEWES, P.O. Drawer 2131,
Jackson, Mississippi 39205

MR. M. J. BOOKER
Marine Corps Base,
Twentynine Palms, California 92278

MR. W. O. BORDEN
Stanford Research Institute
Menlo Park, California 94025

MR. HENRY C. BOSLEY
Navajo Army Depot
Flagstaff, Arizona 86001

MR. S. A. BRAHIN
Thiokol Chemical Corporation
Bristol, Pennsylvania 19007

MR. H. A. BRAMEIER
Aberdeen Proving Ground
Aberdeen Proving Ground, Md. 21001

MR. FRANK BRANDAU
Austin Powder Company
Cleveland, Ohio 44113

MR. A. T. BRASWELL
Red River Army Depot
Texarkana, Texas 75501

MR. C. A. BREEDING
ASESB
Washington, D.C. 20315

MR. BILLY A. BROOKS
U. S. Army Missile Command
Huntsville, Alabama 35809

DR. BILLINGS BROWN
Institute for Defense Analyses
Arlington, Virginia 22202

MR. J. A. BROWN
Esso Research & Engineering Co.
Linden, New Jersey 07036

MR. O. R. BROWN
AFSC (SCMT)
Andrews AFB, Maryland 20331

MR. THOMAS F. BROWN
U. S. Naval Ordnance Laboratory
Silver Spring, Maryland 20910

MR. THOMAS P. BROWNE
U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

MR. HAROLD G. BUCHANAN
Ballistic Research Laboratories
Aberdeen Proving Ground, Md. 21005

MR. ARTHUR K. BUCKNER
Kansas Army Ammunition Plant
Parsons, Kansas 67357

DR. GEORGE BUGLIARELLO
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

MR. PAUL A. BUMBAUGH
Letterkenny Army Depot
Chambersburg, Pennsylvania 17201

MR. JOHN M. BURKE
General Precision Systems, Inc.
1077 East Arques Avenue,
Sunnyvale, California 94086

MR. JOHN H. BURNEY
Holston Defense Corporation
Kingsport, Tennessee 37662

MR. D. E. BURNS
U. S. Naval Ammunition Depot
Crane, Indiana 47522

MR. E. H. Buschman
Naval Ordnance Station
Indian Head, Maryland 20640

MR. JOHN A. BUTAS
U. S. Army Sentinel System Command
Huntsville, Alabama 35807

MR. W. W. BUXTON
Aerojet-General Corporation
Sacramento, California 95813

MR. W. W. BYRD
Naval Ordnance Station
Louisville, Kentucky 40214

MR. R. J. CALL
Atlantic Research Corporation
19701 West Goodvale Road
Saugus, California 91350

MR. HARRY L. CALLAHAN
Black & Veatch Consulting Engineers
1500 Meadow Lake Parkway
Kansas City, Missouri 64114

MR. J. L. CAMP
U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

MR. C. J. CAMPBELL
U. S. Army Weapons Command
Rock Island, Illinois 61201

MR. D. L. CAREW
HQ Tenth Air Force (10MME-D)
Richards-Gebaur AFB, Mo. 64030

MR. W. E. CARPER
U. S. Naval Ammunition Depot
Crane, Indiana 47522

MR. W. J. CARROLL, JR.
Trojan Powder Company, Division of
Commercial Solvents Corp.
17 North 7th Street,
Allentown, Pennsylvania 18105

MR. ROBERT M. CARSON
Harry Diamond Laboratories
Washington, D.C. 20438

MR. E. B. CASSLER
Hercules, Incorporated
P.O. Box 98
Magna, Utah 84044

MR. JOHN L. CHAMBERLIN
U. S. Army Materiel Command
Washington, D.C. 20315

MR. W. J. CHARD
ADC, (ADMME-DC)
Ent AFB, Colorado 80912

MR. W. L. CHILDRESS
Thiokol Chemical Corporation
P.O. Box 524
Brigham City, Utah 84302

MR. W. D. CHURCHILL
U.S.Army Engineer Div., Mo River
P.O. Box 103,
Omaha, Nebraska 68101

MR. E. G. CLARK
Deseret Test Center
Fort Douglas, Utah 84113

MR. WILLIAM N. CLAYTON
Badger Army Ammunition Plant
Baraboo, Wisconsin 53913

CPT John D. Clements
Office of The Judge Advocate
Litigation Division, DA
Washington, D.C. 20310

MR. W. B. COLLINS
AFATL (ATZY)
Eglin AFB, Florida 32542

MR. JOHN H. CONLEY
Aberdeen Proving Ground
Aberdeen Proving Ground, Md. 21005

MR. C. J. CORMACK, JR.
Naval Air Systems Command
Washington, D.C. 20360

MR. P. M. CORMIER
Naval Underwater Weapons Research
and Engineering Station
Newport, Rhode Island 02840

MR. G. R. COTNER
NWC, Corona Laboratories
Corona, California

MR. W. C. COURTRIGHT
Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

MR. G. H. COWAN
U. S. Army Munitions Command
Dover, New Jersey 07801

MR. G. R. COWAN
E. I. du Pont de Nemours & Co.
Eastern Laboratory
Gibbstown, New Jersey 08027

MR. NEWELL E. COX, JR.
Hq ATC (ATISD-GM)
Randolph AFB, Texas 78148

MR. EDWARD L. CRAIG
Naval Weapons Station, Code 15000
Concord, California 94520

MR. E. E. CRAIN
Sierra Army Depot
Herlong, California 96113

MR. L. V. CRAYCRAFT
NWC, Corona Laboratories
Corona, California

MR. A. J. CROUSE
White Sands Missile Range
White Sands, New Mexico 88002

MR. J. W. CROWLEY
The Susquehanna Corporation
Alexandria, Virginia 22314

DR. CHARLES B. DALE
Naval Ordnance Station
Indian Head, Maryland 20640

MR. G. H. DAMON
Bureau of Mines, U. S. Department
of the Interior
Washington, D.C. 20240

MR. J. W. DANIEL
Hq PACAF (DMWP)
APO San Francisco 96553

MR. J. L. DARGAN, JR.
24th Special Operations Wing
P.O. Box 122
Balboa Heights, Canal Zone

MAJ DANIEL C. DAUBE, USAF
Air Force Western Test Range (WTOSM)
Vandenberg AFB, California 93437

MR. J. H. DAUGHERTY
Aberdeen Proving Ground
Aberdeen Proving Ground, Md. 21005

MR. H. L. DEANS
U. S. Army Materiel Command
Washington, D.C. 20315

MR. LAWRENCE DEL REGNO
DCASR
Dallas, Texas 75201

MR. ALEXANDER DENES, JR.
Pacific Missile Range
P.O. Box 4, Code 175
Point Mugu, California 93041

LTC JAMES F. DEVINNEY
Indiana Army Ammunition Plant
Charlestown, Indiana 47111

MR. H. X. DI GRAZIA
Lawrence Radiation Laboratory
P.O. Box 808
Livermore, California 94550

MR. NORVAL G. DOBBS
Ammann & Whitney
111 Eighth Avenue,
New York, N.Y. 10011

MR. B. M. DOCHERTY
Assistant General Counsel
Department of the Army
Washington, D.C. 20310

MR. B. J. DOCTOR
3415 Tech School (TSOP)
Lowry AFB,
Denver, Colorado 80230

MR. J. C. DOHERTY
U.S. Naval Ordnance Laboratory
White Oak, Silver Spring, Md. 20910

MR. L. A. DOHERTY
Joliet Army Ammunition Plant
P.O. Box 871
Joliet, Illinois 60434

MR. LYLE O. DONALDSON
Hq 22nd Air Force
Travis AFB, California 94535

MR. F. N. DRINKARD
Naval Ordnance Station
Indian Head, Maryland 20640

MR. THERON W. DRISCOLL
DCASR, P.O. Box 7478,
Philadelphia, Pa. 19101

LTC WILLIAM H. DUGAN
Hq AFSC (SCIZM)
Andrews AFB, Washington, D.C. 20331

MR. HENRY C. DYER
NASA, Marshall Space Flight
Center, Alabama 35812

MR. REGINALD C. EAST, JR.
Hq 2AF (DM4E)
Barksdale AFB, Louisiana 71110

MR. R. E. ECHELBERGER
2705th Airmunitions Wing
OOAMA (OOYS)
Hill AFB, Utah 84401

MR. H. F. EDEN
Arthur D. Little, Inc.
Cambridge, Mass. 02140

MR. RICHARD S. EGLY
Commercial Solvents Corporation
1331 South First Street,
Terre Haute, Indiana 47808

MR. L. C. ELLIS
Atlas Chemical Industries, Inc.
Chattanooga, Tennessee 37401

MR. F. M. ELSASSER
60th Military Airlift Wing (60MSO)
Travis AFB, California 94535

MR. D. E. ENDSLEY
1002d IG Gp (AFIAS-G2), USAF,
Norton AFB, California 92409

MR. R. C. ERVIN, JR.
Savanna Army Depot
Savanna, Illinois 61074

MR. L. C. ESTUS
Hercules, Inc.
Sunflower Army Ammunition Plant
Lawrence, Kansas 66044

MISS MARJORIE W. EVANS
Stanford Research Institute
333 Ravenswood Avenue,
Menlo Park, California 94025

MR. R. L. EVANS
DCASR, Cleveland
1240 East Ninth Street,
Cleveland, Ohio 44199

MR. L. C. EWING, JR.
Atlas Chemical Industries, Inc.
Volunteer Army Ammunition Plant
Chattanooga, Tennessee

MR. J. M. FAIRCHILD
Aerojet-General Corporation,AFPRO
P.O. Box 15846
Sacramento, California 95813

MR. R. W. FALCONER
Aerospace Corporation
P.O. Box 1821,
Vandenberg AFB, California 93437

MR. G. L. FEAZELL
U. S. Army Materiel Command
Washington, D.C. 20315

MR. J. M. FEINGLAS
436th Military Airlift Wing,
Dover AFB, Delaware 19901

MR. ALFRED FERNANDES
NAVORDSYSCOM (043B)
Navy Department
Washington, D.C. 20360

MR. L. V. FERNANDEZ, JR.
White Sands Missile Range
White Sands, New Mexico 88002

MR. K. L. FICHTER
Picatinny Arsenal
Dover, New Jersey 07801

MR. F. J. FIDELL
Frankford Arsenal (SMUFA-C7000)
Philadelphia, Pennsylvania 19137

MR. DARREL R. FIELDS
Naval Weapons Evaluation Facility
Kirtland AFB,
Albuquerque, New Mexico 87117

MR. WILLIAM S. FILLER
U. S. Naval Ordnance Laboratory
White Oak, Silver Spring, Md. 20910

MR. WILLIAM T. FINE
U. S. Naval Ordnance Laboratory
White Oak, Silver Spring, Md. 20910

MR. RAYMOND G. FINNEY
Indiana Army Ammunition Plant
Charlestown, Indiana 47111

LTC MORTON FISCHER
AFATL (ATZY)
Eglin AFB, Florida 32542

MR. HERBERT B. FLETCHER
Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

MR. FRED L. FOLTZ
Newport Army Ammunition Plant
Newport, Indiana 47966

MR. CHARLES B. FORD
James M. Castle, Inc.
918 Vine Street,
Philadelphia, Pennsylvania 19107

MR. IAN C. FORREST
Yuma Proving Ground
Yuma, Arizona 85364

MR. DOUGLAS F. FOSMIRE
Hq 1st Air Force (MME-D)
Stewart AFB, New York 12250

MR. JOHN D. FRAZIER
McDonnell Douglas Corporation
St. Louis, Missouri 63166

MR. ROBERT M. FRISTROM
APL, Johns Hopkins University
8621 Georgia Avenue,
Silver Spring, Maryland 20910

MR. S. C. FROEHLING
Brunswick Corporation
Box 300
Sugar Grove, Virginia 24375

COL W. E. FROEMMING
U. S. Army Materiel Command
Washington, D.C. 20315

MR. F. H. FRYE
6515th C&E Maint. Sq.(FTMML-41)
Edwards AFB, California

MR. BRUNO FURINI
E. I. du Pont de Nemours & Co.
Pompton Lakes, New Jersey 07442

MR. THOMAS E. FURNISH
Jefferson Proving Ground
Madison, Indiana 47250

MR. F. P. GALLES
Naval Torpedo Station, Code 011
Keyport, Washington 98345

MR. GEORGE B. GAPPA
Naval Supply Center (Code 700)
937 North Harbor Drive,
San Diego, California 92131

MR. A. B. GARDNER
DCSPER, Department of the Army
Washington, D.C. 20315

MR. C. A. GARLAND, JR.
Association of American Railroads
2 Pennsylvania Plaza
New York, New York 10001

MR. FRANK C. GIBSON
Explosives Research Center
Bureau of Mines, U.S.Dept of Interior
4800 Forbes Avenue,
Pittsburgh, Pennsylvania

MR. L. E. GILBERT
AFFDL/FDTS
Wright-Patterson AFB, Ohio 45433

MR. JOSEPH GILLEESE
Umatilla Army Depot
Umatilla, Oregon 97838

MR. C. A. GILMORE
Anniston Army Depot
Anniston, Alabama 36201

MR. C. R. GOFF
Day & Zimmermann, Inc.,Lone Star Div.,
Texarkana, Texas 75501

MR. DAVID R. GOODRICH
American Cyanamid Co.
1937 West Main Street,
Stamford, Conn. 06904

MAJ LANDON E. GOOKIN, JR.
AAFTS (FTBLI)
Edwards AFB, California 93523

MR. R. W. GOTT
Hercules, Inc.
Wilmington, Delaware 19899

MR. GEORGE M. GOUGLER
AFPRO (CMRE)
Hill AFB, Utah 84401

MR. JAMES L. GOURLEY
Naval Ordnance Station
Louisville, Kentucky 40214

MR. A. J. GRAFFEO
DA, OCRD, P&ES Division
Washington, D.C. 20310

MR. JAMES W. GRAVES
Lone Star Army Ammunition Plant
Texarkana, Texas 75501

MR. JESSIE F. GREEN
Naval Ordnance Systems Support Office
4297 Pacific Highway
San Diego, California 92110

MR. E. N. GRIFFIN
Hercules, Inc., ABL
Cumberland, Maryland 21502

MR. KENNETH T. GRIFFIN
ARO, Inc.
Arnold Air Forst Station, Tenn. 37389

MR. ABRAHAM GRINOCH
Picatinny Arsenal
Dover, New Jersey 07801

MR.LEO J. GROSS
Fairfield Scientific Corp.
One Goddard Drive,
Rockaway, New Jersey 07866

MR. CLIFFORD P. HAHN
American Institutes for Research
Silver Spring, Maryland 20910

MR. A. E. HAMILTON
U.S. Naval Ammunition Depot
Crane, Indiana

MR. BRYAN HANCOCK
Naval Ordnance Station
Indian Head, Maryland 20640

MR. C. J. HANEY
Defense Atomic Support Agency
Washington, D.C. 20305

MR. H. A. HANNA
Mason & Hanger-Silas Mason Co.,
Burlington, Iowa 52601

MR. MADS W. HANSEN
Sierra Army Depot
Herlong, California 96113

MR. E. M. HANVEY
Anniston Army Depot
Anniston, Alabama 36201

MR. BILLY R. HARPER
Dixie Chemicals Company, Inc.
P.O. Box 696
Camden, Arkansas 71701

LTC WILLIAM R. HARRIS
US Army Armor and Engineer Board
Fort Knox, Kentucky 40121

MR. FRED X. HARTMAN
NASA - Safety Office
Kennedy Space Center, Florida 32899

MR. ERSKINE E. HARTON, JR.
NASA Headquarters (Code DY)
Washington, D.C. 20546

MR. JOHN W. HASSLER
HOLEX, Incorporated
2751 San Juan Road
Hollister, California 95023

MR. CHARLES R. HATCHER
AMC Safety Field Office
Lexington-Blue Grass Army Depot
Lexington, Kentucky 40507

MR. W. G. HAYDEN
Olin Mathieson Chemical Corporation
East Alton, Illinois 62024

MR. E. LEE HEAD
Remington Arms Company, Inc.
Lake City Army Ammunition Plant
Independence, Missouri 64050

MR. AL HEESEMAN
Wyle Laboratories
1841 Hillside, Box 160
Norco, California 91760

MR. O. K. HEINEY
Jet Propulsion Laboratory
Pasadena, California 91103

MR. F. G. HENDERSON
USAF, 1002d IG GP (AFIAS-G2)
Norton AFB, California 92409

MR. W. PAUL HENDERSON
Edgewood Arsenal
Edgewood Arsenal, Maryland 21010

MR. J. A. HERICKES
Atlantic Research Corporation
Alexandria, Virginia 22213

MR. R. C. HERMAN
ASESB
Washington, D.C. 20315

MR. JOHN J. HERRICK
Naval Ammunition Depot
Portsmouth, Virginia 23702

MR. HENRY HEUBUSCH
Bell Aerosystems
P.O. Box 1
Buffalo, New York 14240

MR. WARREN J. HEWES
Susquehanna Corporation
P.O. Box 38
Gainesville, Virginia 22065

MR. ORA D. HICKERSON
Iowa Army Ammunition Plant
Burlington, Iowa 52601

MR. JOE HIGGS
Corps of Engineers
Huntsville, Alabama

MR. T. R. HIKEL
The Boeing Company
P.O. Box 3999
Seattle, Washington 98124

MR. THOMAS P. HILL
Day & Zimmermann, Inc.
1700 Sansom Street,
Philadelphia 3, Pa.

MR. JAMES F. HISS
AMC Safety Field Office(Lex)
Lexington, Kentucky 40507

MR. E. D. HOFFARTH
1st Air Force (MME-D)
Stewart AFB, New York 12250

COL GEORGE J. HOLLY
U. S. Army Materiel Command
Washington, D.C. 20315

MR. P. N. HOLMES
Lockheed Propulsion Company
P.O. Box 111,
Redlands, California 92374

MR. JOHN E. HOOVER
Hercules, Inc.
Radford Army Ammunition Plant
Radford, Virginia 24141

MR. CLIFFORD A. HORN
Olin Mathieson Chemical Corporation
Indiana Army Ammunition Plant
Charlestown, Indiana 47111

MR. FRANCIS Z. HOUGH
Naval Air Systems Command Headquarters
Code AIR-09E3
Washington, D.C. 20360

MR. A. E. HOWARD
White Sands Missile Range
White Sands, New Mexico 88002

MR. WARREN S. HUBBARD
Jefferson Proving Ground
Madison, Indiana 47250

MR. J. R. HUBER
Eastern Rotorcraft Corporation
Doylestown, Pennsylvania 18901

MR. GEORGE F. HUGHES, JR.
Naval Weapons Station
Yorktown, Virginia 23491

MR. JAMES L. HUME
Lexington-Blue Grass Army Depot
Lexington, Kentucky 40507

MR. PAUL A. HUMPHREY
DHEW, U. S. Public Health Service
National Air Pollution Control Admin
Durham, North Carolina 27701

MR. CARL R. HUTTER
E. I. du Pont de Nemours & Co.
Pompton Lakes Development Lab
Pompton Lakes, New Jersey 07442

MR. WARD B. JAMES
Naval Ammunition Depot Bangor
P.O. Box 218
Edison, Washington 98246

MR. JOHN E. JAMISON
Mason & Hanger-Silas Mason Co.
Burlington, Iowa 52601

MR. EVAN A. JARBOE
Naval Ammunition Depot Bangor, RR1, Box 215,
Silverdale, Washington 98383

MR. FRANCIS L. JENNE
Jet Propulsion Laboratory
Pasadena, California 91103

MR. LEO M. JERCINOVIC
Sandia Corporation
P.O. Box 5800
Albuquerque, New Mexico 87115

MR. LOUIS JEZEK
U. S. Army Materiel Command
Washington, D.C. 20315

MR. CLARENCE B. JOHNSON
Naval Facilities Engineering Command
Seattle, Washington 98119

MR. E. W. JOHNSON
Explosive Technology
P.O. Box KK
Fairfield, California 94533

MR. RICHARD K. JOHNSON
North American Rockwell Corporation
Downey, California 90241

MR. WEBB P. JONES
Yuma Proving Ground
Yuma, Arizona 85364

MR. ROYAL J. KAHLER
Mason & Hanger-Silas Mason Co.
Box H, Grand Island, Nebraska 68801

MR. ERNEST M. KANE
Naval Missile Center, Code 5332
Point Mugu, California 93041

MR. KENNETH KAPLAN
URS Systems Corporation
1811 Trousdale Drive,
Burlingame, California 94010

MR. E. E. KATCHER
Naval Air Systems Command
Washington, D.C. 20360

MR. HOWARD KATZ
Naval Air Systems Command
Washington, D.C. 20360

MR. JAMES H. KELLY, JR.
Hercules Inc.
Radford Army Ammunition Plant,
Radford, Virginia 24141

MR. J. R. KELSO
Defense Atomic Support Agency
Washington, D.C. 20305

MR. R. H. KIEKE
ASESB
Washington, D.C. 20315

MR. PAUL V. KING
General Electric Company
Bay St Louis, Mississippi 39520

MR. C. N. KINGERY
BRL - TBL, ATTN AMXRD-BTD
Aberdeen Proving Ground, Md. 21005

MR. ALBERT C. KLOOCK
U. S. Army Sentinel System Command
Huntsville, Alabama 35807

MR. B. L. KNASEL
ASESB
Washington, D.C. 20315

MR. C. C. KNOLES
Pueblo Army Depot
Pueblo, Colorado 81101

MR. A O. KOON, JR.
Hercules, Inc. ABL
Cumberland, Maryland 21502

MR. MILLARD L. KOPATCH
Ballistic Research Laboratories
Aberdeen Proving Ground, Md. 21005

MR. L. V. LAITE, JR.
Bendix, Launch Support Division
Kennedy Space Center, Fla. 32815

MR. JOHNIE L. LANE
Naval Ammunition Depot
St. Juliens Creek,
Portsmouth, Virginia 23702

MR. JEAN L. LARSEN
Letterkenny Army Depot
Chambersburg, Pennsylvania 17201

LTC WILLIAM G. LAWHEAD
Holston Army Ammunition Plant
Kingsport, Tennessee 37662

MR. H. L. LAWRENCE
Beech Aircraft Corporation
P.O. Box 631
Boulder, Colorado 80302

MR. POPE A. LAWRENCE
National Air Pollution Control Admin
Health, Education & Welfare
Washington 25, D.C.

MR. H. T. LAWSON
Research & Dev Dir, T&RE Lab
U. S. Missile Command
Redstone Arsenal, Alabama 35809

MR. C. S. LEIGH
Northrop Carolina, Inc.
Asheville, North Carolina 28802

MR. T. L. LACOPO
Joliet Army Ammunition Plant
UNIROYAL, Inc.
Joliet, Illinois 60434

MR. F. E. LINDSAY
HQ TAC (OSMEN)
Langley AFB, Va. 23365

MR. EDWIN T. LOSS
Hq Military Traffic Mgt & Ter Ser
Washington, D.C. 20315

MR. JOHN W. LOWELL
ASESB
Washington, D.C. 20315

MR. ILMAR LUSIS
TRW Systems Group
Remondo Beach, California

MR. R. M. LUSSIER
Naval Base
Newport, Rhode Island 02840

MR. R. L. LUTZ
DCASR, St. Louis
St. Louis, Missouri 63101

MR. K. S. MACY
Picatinny Arsenal
Dover, New Jersey 07801

MR. RICHARD MAGUIRE
AAFTC (FTBLI)
Edwards AFB, California 93523

MR. W. H. MANDLECO
Gulf General Atomic Inc
P.O. Box 608
San Diego, California 92112

MR. B. C. MANN
Hq Air Force Systems Command
Andrews AFB, Washington, D.C. 20331

MR. F. W. MARCH
Naval Supply Center,
San Diego, California 92131

MR. V. L. MARTUCCI
DCASR, New Jersey,240 Rt.22,
Springfield, New Jersey 07081

MISS BEVERLY J. MAST
ASESB
Washington, D.C. 2031

MR. CHARLES M. MASTEN
Aerojet General Corporation
P.O. Box 15847
Sacramento, California 95813

MR. J. F. MATTINGLY
Naval Ordnance Station, Code SAOA
Indian Head, Maryland 20640

MR. L. V. MAXWELL
U. S. Naval Ammunition Depot
McAlester, Oklahoma 74501

MR. WILLIAM MC BRIDE
Naval Weapons Station
Yorktown, Virginia 23491

MR. F. R. MC CANN
U. S. Army Engineer District, Louisville
Louisville, Kentucky 40201

MR. W. C. MC CAY
Longhorn Army Ammunition Plant
Marshall, Texas 75670

MR. THOMAS M. MC COMB, JR.
NASA, Wallops Station
Wallops Island, Virginia 23337

MR. C. A. MC GEE
North American Rockwell Corp.
4300 E. 5th Avenue,
Columbus, Ohio 43216

MR. W. R. MC KEEN
U. S. Naval Ammunition Depot,
Crane, Indiana

MR. DUANE MC SMITH
NASA Langley Research Center
Hampton, Virginia 23365

MR. DON R. MEISSNER
Tooele Army Depot
Tooele, Utah 84074

MR. FRED A. MENGES
Goodyear Aerospace Corp.
Akron, Ohio 44315

MR. F. C. MERRILL
Red River Army Depot
Texarkana, Texas 75501

MR. PAUL MIKA
McDonnell Astronautics Co.
P.O. Box 600
Titusville, Florida 32780

MR. J. L. MILLS
Pace Corporation
Memphis, Tennessee 38102

MR. J. J. MOLLOY
North American Rockwell Corp.
2300 E. Imperial Highway
El Segundo, California 90245

MR. L. J. MONTESI
Naval Ordnance Laboratory
White Oak, Silver Spring, Md. 20910

MR. L. C. MONTGOMERY
Jet Propulsion Laboratory
Pasadena, California 91103

MR. C.J. MOORE
Naval Ammunition Depot
Hawthorne, Nevada 89415

MR. J. W. MOORE
Honeywell Ordnance Division
600 Second Street, N.
Hopkins, Minn.

MR. A. J. MORGAN
AFFTC (FTBLI)
Edwards AFB, California 93523

MR. LARRY E. MORGAN
Joliet Army Ammunition Plant
Joliet, Illinois 60436

MR. DELLAR A. MOTT
-tronics, Div of Northrop Corp.
Anaheim, California 92801

Mr. CARL R. MUNCY
Naval Ammunition Depot
Crane, Indiana 47250

MR. G. S. MUSTIN
Naval Ordnance Systems Command
Washington, D.C. 20360

MR. J. L. MURPHY
Thiokol Chemical Corporation
Huntsville, Alabama

MR. R. L. MYERS
USAMC Field Safety Agency
Charlestown, Indiana 47111

MR. BEN NAKASHIMA
AAFTC (FTYCA
Edwards AFB, California 93523

MRS. HYLA S. NAPADENSKY
IIT Research Institute
10 W. 35th Street, Chicago,
Illinois 60616

MR. D. E. NELSON
U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

MR. G. M. NEWCOMER
NASA Safety Office, Code DY
Washington, D.C. 20546

MR. J. J. NIEMITZ
U. S. Naval Ammunition Depot, Oahu
FPO San Francisco 96612

LT D. S. NOBLE, USN
Naval Postgraduate School
Monterey, California 93940

MR. H. S. NORTH
Sandia Corporation
P.O. Box 5800
Albuquerque, New Mexico 87115

MR. W. K. NYSTROM
Naval Weapons Station
Concord, California 94520

MR. J. J. O'DRISCOLL, JR.
Atlas Chemical Industries, Inc.
Wilmington, Delaware 19899

CPT L. R. OLSEN
Naval Ordnance Station
Indian Head, Maryland 20640

MR. B. A. OSBORNE
Atlantic Research Corporation
West Hanover, Massachusetts 02339

LCDR W. D. O'TOOLE
USN, ACNO for Safety
Washington, D.C. 20350

MR. H. H. OZENGHAR
DCASE, Anaheim
Anaheim, California 92805

Mr. J. C. PALERMO
McDonnell Astronautics Co.
P.O. Box 600
Titusville, Florida 32780

MR. D. G. PATTERSON
HQ USAREUR & 7TH ARMY,
APO New York 09430

MR. J. W. PEARCE
Sandia Laboratories Livermore
P.O. Box 969
Livermore, California 94550

MR. R. F. PEAK
The Boeing Company, Aerospace Div.,
Seattle, Washington 98124

MR. H. D. PELL
Custom Materials, Inc.
Chelmsford, Massachusetts 01824

MR. T. M. PERDUE
U. S. Army Sentinel System Command
Huntsville, Alabama 35807

MR. R. G. PERKINS
ASESB
Washington, D.C. 20315

LTC W. H. PERRIS
HQ, USAF, AFIIS, Pentagon
Washington, D.C. 20330

MR. J. P. PERRY
Eastern Rotorcraft Corp.
Doylestown, Pennsylvania 18901

MR. CARL F. PETERS
Umatilla Army Depot
Hermiston, Oregon 97838

MR. G. W. PETERSON
Naval Missile Center, Code 5220-1
Point Mugu, California 93041

MR. J. T. PETRICK
Naval Weapons Laboratory
Dahlgren, Virginia 22448

MR. J. W. PETTIGREW
USAE Waterways Experiment Station
Vicksburg, Mississippi 39180

MR. J. PHILIPSON
1485 Old House Road
Pasadena, California 91107

MR. M. FRANK PICKETT
Naval Weapons Center Corona Labs
Corona, California

MR. R. A. PINCUS
NASA Langley Research Center
Hampton, Virginia 23365

MR. M. J. PISTEK
Aerospace Div., Atlas Chemical
Valley Forge, Pa. 19481

MR. W. A. PLATT
AFSC, Space & Missile System Organization
AF Unit Post Office
Los Angeles, California 90045

MR. D. B. PLEDGER
NAVFACENGCOM
Bu Yards & Docks Annex
Washington, D.C. 20390

MR. R. F. POHL
U. S. Army Munitions Command
Dover, New Jersey 07801

MR. J. R. POLSON
Mason & Hanger-Silas Mason Co.
Burlington, Iowa 52601

MR. C. K. RACHEL
Hughes Aircraft Company
P.O. Box 11337
Tucson, Arizona 85706

MR. H. J. RAFAEL
HQ ADC, Ent AFB, Co 80912

MR. B. W. RATTERMAN, SR.
U. S. Army Armor Center
Fort Knox, Kentucky 40121

MR. C. W. REDMAN
Cornhusker Army Ammunition Plant
Grand Island, Nebraska 68801

DR. W. A REDMAN, JR.
Environmental Health Center
U. S. Naval Ammunition Depot,
Crane, Indiana 47522

MR. K. R. REGIER
TRW Systems, Health & Safety Dept
Redondo Beach, California 90278

MR. G. L. RHODES
Sandia Laboratories Livermore
Livermore, California 94550

MR. J. M. RICHARDSON
Sperry Rand Corporation
Louisiana Army Ammunition Plant
Shreveport, Louisiana 71102

MR. J. J. RIDGE
AFATL (ATZY)
Eglin AFB, Florida 32542

MR. P. G. RIVETTE
Naval Weapons Center Corona Labs
Corona, California

MR. R. M. RINDNER
Picatinny Arsenal, SMUPA-DE2
Dover, New Jersey 07801

MR. R. G. ROBBINS
U.S. Army Air Defense Command
Ent Air Force Base
Colorado Springs, Colorado 80912

MR. L. L. ROBERTS
Marshall Space Flight Center
Huntsville, Alabama 35812

MR. MANUEL RODARTE
U. S. Naval Weapons Station
Seal Beach, California 90740

MR. D. A. ROESCH
McDonnell Douglas Astronautics Co.
Cocoa Beach, Florida 32931

LTC LYNN ROGERS, USAF
DCASR (DCRB-QS
Boston, Massachusetts 02210

MR. R. D. RONKIEWICZ
Volunteer Army Ammunition Plant
Chattanooga, Tennessee 37401

MR. E. I. ROSS
AMC Ammunition School
Savanna Army Depot,
Savanna, Illinois 61074

MR. R. R. ROYALL
Holston Army Ammunition Plant
Kingsport, Tennessee

MR. H. M. ROYLANCE
Naval Ordnance Systems Command
Washington, D.C. 20360

MR. C. J. ROZAS
North American Rockwell Corporation
Rocketdyne Division
Canoga Park, California 91304

MR. K. G. RUCKER
E. I. du Pont de Nemours, Eastern Lab
Gibbstown, New Jersey 08027

MR. R. A. SAHLIN
Remington Arms Company
Bridgeport, Connecticut 06602

MR. J. J. SAMS
Bendix Corporation
110 Highview
Coca, Florida

MR. J. A. SAMUELSON
Lockheed Missiles & Space Company
Santa Cruz, California 95060

MR. E. G. SAVAGE
McDonnell Douglas Corp
St. Louis, Missouri 63166

MR. F. R. SAWYER
NASA, Wallops Station
Wallops Island, Virginia 23337

MR. R. B. SAWYER
Naval Ordnance Systems Command
Washington, D.C. 20360

MR. J. C. SCHRADER
Fort Wingate Army Depot
Gallup, New Mexico 87301

MR. C. W. SCHULTZ
Association of Amer. Railroads
Bureau of Explosives
Edison, New Jersey 08817

1LT E. K. SCHOPPAUL, USMC
Supply Company, H&SBn, MCB
Twentynine Palms, California 92278

MR. HOWARD L. SCHULTZ
AMC Safety Field Office
Lexington-Blue Grass Army Depot
Lexington, Kentucky 40507

MR. D. F. SCHWAMB
Military Ocean Terminal, Sunny Point
South Port, North Carolina 28461

MR. W. L. SCHWOYER
Trojan, Div. of Commercial Solvents Corp.
17 North 7th Street, Allentown, Pa. 18105

MR. H. T. SCOTT
Atlantic Research Corporation
Alexandria, Virginia

MR. J. E. SEAGRAVES
Goodyear Aerospace Corp.
Akron, Ohio 44315

MR. R. H. SEAVERS
U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

MR. R. F. SELLARS
Martin-Marietta Corporation
P.O. Box 5837
Orlando, Florida 32805

MR. R. F. SHAW, J R.
Honeywell, Inc.
Twin Cities Army Ammunition Plant
New Brighton, Minnesota

MR. D. T. SHERIFF
Space & Missile Systems Organization
Norton AFB, California 92409

LTC GEORGE SHERMAN
HQTAC (OSMEN)
Langley AFB, Virginia 23365

MR. J. M. SHINN, JR.
NASA, Langley Research Center
Hampton, Virginia 23365

MR. K. R. SHOPHER
HQ AFLC (MCIAE)
Wright-Patterson AFB, Ohio 45433

MR. C. E. SILK
Olin Mathieson Chemical Corp.
East Alton, Illinois 62024

MR. G. J. SIMMONS
Milan Army Ammunition Plant
Milan, Tennessee 38358

MR. H. C. SIMPKINSON
USATECOM, Safety Division
Aberdeen Proving Ground, Md. 21005

MR. W. H. SIMS
Naval Ordnance Systems Support
Office, Atlantic
Norfolk Naval Shipyard, Bldg 62,
Portsmouth, Virginia 23709

MR. ALFRED I. SIMON
Custom Materials, Inc.
Chelmsford, Massachusetts 01824

MR. J. E. SINCLAIR
Naval Postgraduate School
Monterey, California 93940

MR. M. E. SITZMANN
Naval Ordnance Laboratory
Silver Spring, Md. 20910

MR. R. C. SKINNER
U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

MR. G. E. SLIGHT
U. S. Naval Ammunition Depot
Crane, Indiana 47522

MR. A. F. SLIWA
Naval Ordnance Systems Command
Washington, D.C. 20360

MR. CHARLES B. SMITH
Office of Hazardous Materials, DOT
Washington, D.C. 20590

MR. GEORGE L. SMITH
Remington Arms Company
939 Barnum Avenue,
Bridgeport, Connecticut 06602

MR. REX L. SMITH
Naval Weapons Center, Corona Labs
Corona, California

MR. STEVEN I. SOMMER
Worklon Div of Superior Surg. Mfg. Co.
63 New York Avenue,
Huntington, New York 11743

MR. F. J. SOVINSKI
Lake City Ammunition Plant
Independence, Missouri 64050

MR. NEIL C. SPENCER
Pan American World Airways, Inc.
Mail Unit 5260
Patrick AFB, Florida 32925

MR. ROBERT H. SPOTZ
Naval Ordnance Station
Indian Head, Maryland

MR. M. P. SQUIRES
White Sands Missile Range
White Sands, New Mexico 88002

MR. STANLEY W. STANICK
Aerospace Corporation
P.O. Box 95085
Los Angeles, California 90045

MR. BEN T. STEPHENS
Pueblo Army Depot
Pueblo, Colorado 81001

MR. C. J. STEVENS
Naval Facilities Engineering Command
Department of the Navy
Washington, D.C. 20390

MR. F. R. STEVENSON
Magazine Dept, Naval Station
Newport, Rhode Island 02840

MR. BERT F. STEVES
Black & Veatch Consulting Engineers
1500 Meadow Lake Parkway
Kansas City, Missouri 64114

MR. B. C. STOUT
AF Missile Dev. Center
Hollman AFB, New Mexico 88330

MR. H. K. STRASS
NASA, Adv. Research & Tech.
Washington, D.C. 20546

MR. W. W. STRUCK
Indiana Army Ammunition Plant
Charlestown, Indiana 47111

MR. M. T. STUCKEY
Thiokol Chemical Corporation
P.O. Box 241,
Elkton, Maryland 21921

MR. SHIRLEY H. STURTZ
AF Logistics Command (MCTPP)
Wright-Patterson AFB, Ohio 45433

MR. O. J. SUNDSTROM
HQ USAF (AF SSSCA)
Washingoton, D.C. 20330

MR. J. C. SWEAT
NASA, Kennedy Space Center
Kennedy Space Center, Florida 32899

MR. W. J. TAYLOR
Atlas Chemical Industries, Inc.
Wilmington, Delaware 19899

MR. G. L. TEW
Ammunition Procurement & Supply Agency
Joliet, Illinois 60436

MR. FRED A. THAYER
6555th Aerospace Test Wing
Patrick AFB, Florida 32925

MR. ROBERT L. THOMAS
AFFTC (AFRPL) RPMX
Edwards AFB, Calif. 93523

MR. WILLIAM B. THOMAS
U. S. Army Missile Command
Redstone Arsenal. Alabama 35809

MR. W. C. THOMAS
Naval Undersea Warfare Center
Pasadena, California 91107

MR. MONTE S. THOMPSON
AFETR Safety Office (ETDM)
Patrick AFB, Florida 32925

MR. ROBERT E. THOMPSON
Brunswick Corporation
Needham, Massachusetts 02192

MR. JEFFERSON R. THORNTON
McDonnell Astronautics Co.
P.O. Box 600
Titusville, Florida 32780

MR. RONALD W. THORNTON
Hercules, Inc.
Kenvil, New Jersey 07847

MR. HENRY L. THORPE
Aerojet-General Corporation
Downey, California 90241

MR. WILLIAM P. TODSEN
USA Corps of Engineers, Omaha
6012 U.S.Post Office & Court House
Omaha, Nebraska 68102

MR. A. D. TOLINS
Naval Facilities Engineering Command
Yards & Docks Annex
Washington, 25, D.C.

MR. H. L. TRACY
Space Div of North Amer Rockwell Corp.
12214 Lakewood Blvd, Mail Zone EA 19
Downey, California 90241

MR. S. MAYNARD TURK
Hercules, Inc.
Wilmington, Delaware 19899

MR. F. E. TURNER
The Marquardt Corporation
16555 Saticoy Street,
Van Nuys, California 91406

MR. ROLAND C. UNANGST
Savanna Army Depot
Savanna, Illinois 61041

MR. KENNETH E. VALANT
AMC Ammunition School
Savanna Army Depot,
Savanna, Illinois 61074

MR. C. A. VALESH
Olin Mathieson Chemical Corp.
Badger Army Ammunition Plant
Baraboo, Wisconsin 53913

MR. JOHN M. VALIGORSKY
Savanna Army Depot
Savanna, Illinois 61074

MR. R. W. VAN DOLAH
Bureau of Mines, U.S. Dept of Interior
4800 Forbes Avenue,
Pittsburgh, Pa. 15213

MR. E. W. VAN PATTEN
U. S. Army Munitions Command
Dover, New Jersey 07801

MR. CHARLES C. VESSELS
U. S. Army Sentinel System Command, Kwajalein
ATTN: SENSC-RS, P.O. Box 1500
Huntsville, Alabama 35807

MR. MARTIN VISNOV
Frankford Arsenal
Pitman-Dunn Research Labs
8208 Gilbert Street,
Philadelphia, Pa. 19150

MR. JOSEPH F. VOEGLEIN
Edgewood Arsenal
Edgewood Arsenal, Md. 21010

MR. WILLIAM F. VOSE
Naval Safety Center, NAS
Norfolk, Virginia 23511

MR. STANLEY WACHTELL
Picatinny Arsenal
Dover, New Jersey 07801

MR. T. E. WADE, II
Lawrence Radiation Laboratory
P.O. Box 45
Mercury, Nevada 89023

MAJ R. E. WALLER
Hq SAMSO, AFUPO,
Los Angeles, Calif. 90045

MR. R. C. WANDS
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

LTC LOWELL E. WARD, USAF
HQ Defense Supply Agency
Cameron Station
Alexandria, Virginia 22314

MR. J. H. WASHNOCK
U. S. Army Materiel Command
Washington, D.C. 20315

MR. C. R. WATKINS
HQ USAF AFOCEKB
Washington, D.C. 20332

MR. S. E. WEAVER
Weaver Associates, Inc.
378 Cambridge Avenue,
Palo Alto, California 94306

MR. R. D. WEBSTER
Directorate of Supply
Fort Knox, Kentucky 40121

MR. GARRY WEINGARTEN
Picatinny Arsenal
Dover, New Jersey 07801

MR. S. WEISS
NASA-Lewis Research Center
21000 Brookpark Road, Mail Stop 6-2
Cleveland, Ohio 44135

MR. H. E. WELLS
U. S. Army Materiel Command
Washington, D.C. 20315

MR. JOHN R. WETHERHOLT
Joliet Army Ammunition Plant
P.O. Box 871, Uniroyal, Inc.
Joliet, Illinois 60434

MR. R. W. WHEELER
Explosive Technology
P.O. Box KK
Fairfield, California

MR. J. H. WIEGAND
Aerojet-General Corporation
P.O. Box 15847
Sacramento, California 95813

MR. GEORGE F. WIGGER
Office, Chief of Engineers, USA
Gravelly Point,
Washington, D.C. 20315

MR. J. C. WILBOURNE
Naval Ordnance Station
Indian Head, Maryland 20640

MR. A. G. WILLIAMS
Hq AEDC (AEES)
Arnold AF Station, Tennessee 37389

MR. F. A. WILLIAMS
Lexington-Blue Grass Army Depot
Lexington, Kentucky 40507

MR. FRANK M. WILLIS
E. I. du Pont de Nemours & Company
Eastern Laboratory
Gibbstown, New Jersey 08027

MR. PAUL WILSON
Pacific Missile Range
Code 3264
Point Mugu, California 93041

MR. L. E. WINCKLER
Rohm and Haas Company
Redstone Research Laboratories
Huntsville, Alabama 35807

MR. H. WINER
U. S. Army Materiel Command
Washington, D.C. 20315

MR. WILLIAM J. WIRT
McDonnell Douglas Astronautics Co.
P.O. Box 600
Titusville, Florida 32780

MR. CARL WIUFF
Pace Corporation
Memphis, Tennessee 38102

MR. DILLARD K. WOMACK
U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

MR. GEORGE L. WYATT
SYSTEMED Corporation
MSFC Medical Center, Bldg 4249
Marshall Space Flight Center, Ala. 35812

MR. ROBERT E. YOUNG
Picatinny Arsenal
Dover, New Jersey 07801

MR. THOMAS A. ZAKER
IIT Research Institute
10 West 35 Street,
Chicago, Illinois 60616

MR. HOWARD J. ZIGLER
AMC Ammunition School
Savanna Army Depot
Savanna, Illinois 61074

MR. J. B. ZUZIK
American Cyanamid Company
1937 West Main St.
Stamford, Connecticut 06904

DEPARTMENT OF DEFENSE EXPLOSIVES SAFETY BOARD
2461 EISENHOWER AVENUE
ALEXANDRIA, VIRGINIA 22331-0600

DDESB-KMC

0 7 JUL 2000

MEMORANDUM FOR DDESB RECORDS

SUBJECT: Declassification of Explosives Safety Seminar Minutes

References: (a) Department of Defense 5200.1-R Information Security Program, 14 Jan 1997

(b) Executive Order 12958, 14 October 1995 Classified National Security Information

In accordance with reference (a) and (b) downgrading of information to a lower level of classification is appropriate when the information no longer requires protection at the originally level, therefore the following DoD Explosives Safety Seminar minutes are declassified:

a. AD#335188 Minutes from Seminar held 10-11 June 1959.
b. AD#332709 Minutes from Seminar held 12-14 July 1960.
c. AD#332711 Minutes from Seminar held 8-10 August 1961.
d. AD#332710 Minutes from Seminar held 7-9 August 1962.
e. AD#346196 Minutes from Seminar held 20-22 August 1963.
f. AD#456999 Minutes from Seminar held 18-20 August 1964.
g. AD#368108 Minutes from Seminar held 24-26 August 1965.
h. AD#801103 Minutes from Seminar held 9-11 August 1966.
i. AD#824044 Minutes from Seminar held 15-17 August 1967.
j. AD#846612 and AD#394775 Minutes from Seminar held 13-15 August 1968.
k. AD#862868 and AD#861893 Minutes from Seminar held 9-10 September 1969.

The DoD Explosives Safety Seminar minutes listed above are considered to be public release, distribution unlimited.

DANIEL T. TOMPKINS
Colonel, USAF
Chairman

Attachments:
1. Cover pages of minutes

cc:
DTIC

AD 846-612

MINUTES
OF THE TENTH
EXPLOSIVES SAFETY SEMINAR

SHERATON HOTEL

Louisville, Kentucky

13-15 August 1968

Volume I

Sponsor

ARMED SERVICES EXPLOSIVES SAFETY BOARD
Washington, D. C. 20315

Host

U.S. ARMY MATERIEL COMMAND FIELD SAFETY AGENCY
Charlestown, Indiana

475 attend